DISTRICT OF VANDERHOOF

REPORT SUBMITTED BY URBAN SYSTEMS LTD.

FLOOD PROTECTION PLAN

March 2011

File: 0613.0046.01

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REPORT SUBMITTED TO
THE DISTRICT OF VANDERHOOF

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FLOOD PROTECTION PLAN

Final Report

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APPENDICES

1.0 INTRODUCTION

The District of Vanderhoof is located along the Nechako River, and portions of the developed area of the District are situated within the historic floodplain of the river. Furthermore, the Nechako is a complex water system, and has both natural, uncontrolled contributing areas, as well as dammed and regulated lakes. In particular, a significant portion of the drainage area feeding into the Nechako River upstream of Vanderhoof is regulated by Rio Tinto Alcan's Kenney Dam and Skins Lake spillway.

The purpose of the Kenney Dam and Skins Lake reservoir system is to store water so that it can be used for electricity generation for Alcan's aluminum smelter in Kitimat. As a result of this primary objective, much of the historic flows in the Nechako River are diverted to Kitimat, and the remainder is regulated such that the flow of water in the river is normally not a threat to the District of Vanderhoof.

There are, however, circumstances under which the amount of water flowing into the Skins Lake reservoir is too great, and the discharge through the spillway must be increased to ensure that the reservoir does not fill too quickly and put the dams at risk. In these circumstances, the level of water in the Nechako River can rise to the point where it puts property in Vanderhoof at risk of flooding.

Two major floods have occurred (1976 and 2007), causing both inconvenience and property damage in the community. The most recent flood resulted in the need to plan and prepare for the flood on relatively short notice as the waters encroached on properties and homes. While the leaders of the community and citizens of Vanderhoof were able to respond to the flood threat, responding under emergency circumstances is less than desirable.

In December 2010, the District received funding from Emergency Management BC to develop an emergency flood protection plan for the more populated flood prone areas of Vanderhoof (south and north shore areas – east of Burrard Avenue). While it is recognized that there are other isolated flood prone areas in the community the plan, as summarized in this document, is intended to:

- Supplement the District's current emergency response plan
- Guide the community in managing future flooding situations in a much more proactive and planned way.
- Leverage the District's resources by expediting the response to a potential flood for the more populated areas thus allowing the District more time to protect the other isolated flood areas.

2.0 FLOODPLAIN BOUNDARIES

The first step in the emergency response planning process was to develop an understanding of the potential impact of floods of various magnitudes from relatively low potential impact to relatively significant potential impact. As the flow rate increases, so too does the level of water in the river. And, as the water level rises, more land is inundated, and property and buildings are more likely to be adversely affected.

The probability of a particular flood is defined by the frequency with which it is likely to occur, and is referred to as its return period. This is a statistical measurement of the average frequency that it occurs over an extended period of time. The range of return periods of interest in this study are the 2, 10, 20, 50, 100 and 200 year return periods.

As an illustration, the 100 year return period flood is a flood of such significant magnitude that it has a 1 in 100 chance (or 1% probability) of occurring in any particular year. Likewise, the 10 year flood estimates that flood that has a 1 in 10 chance (or 10% probability) of occurring in any particular year. The lower the value of the return period, the more likely it will occur in any given year, while the higher the value of the return period, the less likely it will occur in any given year.

The flow rates and flood levels associated with the noted return period events were estimated in a previous study carried out by Northwest Hydraulic Consultants (NHC) following the 2007 flood event, and summarized in their report entitled *Vanderhoof Flood Mitigation Study* dated May, 2009. Table 1 shows the projected flow rates and estimated flood levels associated with the full range of floods of concern as provided in this report.

Table 1
Flood Flow Rates and Levels at Burrard Avenue Bridge

Return Period (Years)	Flow Rate (m^3/s)	Flood Level (m)
2	400	635.70
10	620	636.92
20	700	637.19
50	810	637.55
100	890	637.85
200	964	638.19

The noted flood levels are the computed values at the location of the Water Survey of Canada flow measuring gauge fixed to the bridge at Burrard Avenue. It should be noted that actual flood levels further downstream are slightly less. To illustrate, the flood level at the sewage lagoons is computed to be 0.11 meters less during the 2 year return period event and 0.05 meters less during the 200 year event. As a result, for the purpose of this study, the values in this report have been used for setting flood protection levels. For comparison purposes, the 2007 high water event reached an elevation of about 637.5 meters for a period of about 30 days. As shown on Table 1, this elevation corresponds to a flood flow of about 810 m^3/s, and a flood return period of about 50 years.

Using the estimated flood level and topographic maps of the study area, floodplain maps have been created for each flood showing the areas that will be inundated if the flood waters rise to the noted elevations. The series of figures are presented in Appendix A and show the flood elevation and area of inundation for each of the noted return periods for the flood prone areas east of Burrard Avenue. The figures also show the properties which are at risk of flooding during each of the events. For information about flood prone areas outside of this study area, reference the floodplain maps in the NHC *Flood Mitigation Study* – May 2009. It should also be noted that the best topographic maps available for this study have an accuracy of +/- 0.25 meters.

However, as noted in the introduction, the presence of Rio Tinto Alcan's dam system provides a mechanism to manage the rate at which water is discharged into the Nechako River. This results in the opportunity to control the magnitude of a flood through forward planning and management, and an ability under many circumstances to control the level to which the water in the Nechako River at Vanderhoof rises. This ability to regulate the flow in the river is a factor in the proposed approach to flood protection and emergency response planning.

3.0 FLOOD PROTECTION & EMERGENCY RESPONSE PLANS

In ideal circumstances, property which is at risk of being flooded because of its location in a floodplain would be protected by permanent dike works. Such works are typically properly designed earthen barriers which are high enough and strong enough to withstand severe floods. In British Columbia, such structures fall under the *Dike Maintenance Act* and associated regulations. It is a condition of this undertaking that the proposed works would not require approvals under the *Dike Maintenance Act*. As a result, none of the proposed permanent improvements recommended in this report are higher than 1 meter above the surrounding ground level, or higher than the flood elevation associated with the 10 year return period flood event. Furthermore, the works must have regular and sufficient openings such that they do not provide a complete barrier to even relatively frequent high water events.

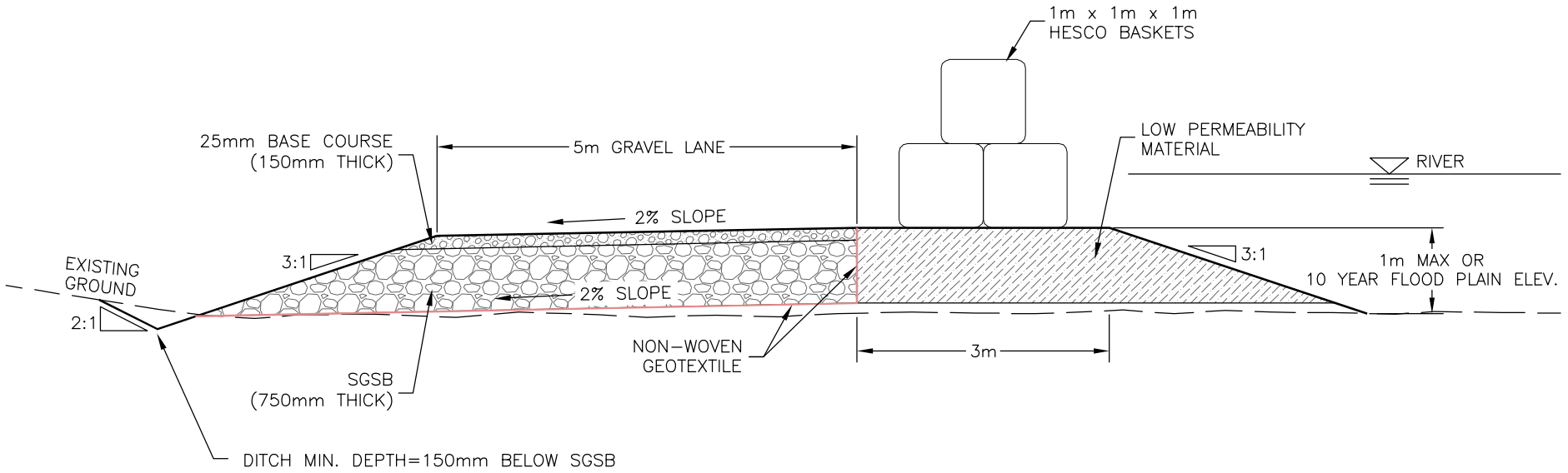
Because of this limitation, the flood protection and emergency response plans focus on two primary measures; the first is permanent works, which can be constructed well in advance of any flood event, and emergency measures, which can be quickly put in place upon the permanent works or in other areas where permanent works have not been constructed or cannot be constructed because of practical constraints.

A cross section of the proposed permanent works is shown on Figure 1. As shown on the figure, the permanent works are proposed to consist of the following key elements:

- A gravel access path or road which is raised above the surrounding ground level and capable of supporting heavy equipment.
- A relatively impermeable portion which will limit the passage of flood waters from the river to land side of the barrier, and upon which emergency works can be constructed.
- Drainage ditches along the access path or road in order to keep standing water away from the base of the road structure in order to preserve its strength.

The proposed locations of the permanent works are shown on the drawing set included in Appendix B. The works, when constructed, will affect a number of parcels of private property on both the north and south shore of the Nechako River. Furthermore, there are two options or variations for the alignment of the proposed permanent works on both the north and south shore. In the case of the south shore, however, a portion of the alignment is common to both options.

FLOOD PROTECTION PLAN



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DISTRICT OF VANDERHOOF FLOOD PROTECTION PLAN

Scale	Date	Figure
NTS	11-03-08	1
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		TYPICAL SECTION

As shown on the key plan in Appendix B, South Alignment Option 1 shows proposed permanent works more or less along the alignment of the emergency works that were constructed to protect against flooding in 2007. This alignment is already cleared and accessible in most places, and could be converted to a permanent access road for the purpose of constructing emergency flood protection works without significant further impact on the properties.

A somewhat shorter route on the south shore is shown as South Alignment Option 2. This alignment would connect to the berm of the sewage lagoon and follow a path closer to the river, thus protecting a slightly larger area with slightly less permanent flood protection works and less disruption to private property.

On the north shore, two options have been examined. North Alignment Option 1 would protect only the portion of Reid Road that is already developed, while North Alignment Option 2 would extend to a large undeveloped area to the east of Reid Road.

In the case of both the north and south shore alignments, only one of the options need be constructed to provide the desired ability to respond during an emergency situation. The preference for one option or another may, at the time the works are actually constructed, depend on the readiness and willingness of the property owner to grant the required statutory right of way within which the works will be constructed.

The intent of the permanent works is to create a continuous pathway upon which emergency works can be constructed in advance of a flood or high water event. The permanent works must be constructed under good conditions, that is, when the land upon which they will be built is not flooded or wet. Furthermore, these works are intended to remain in place at all times. These works are intended to provide protection against the lower levels of high water conditions, but they must be augmented with the provision of sandbags in some areas because of the requirement for providing openings at regular intervals.

During less frequent and more extreme high water events, the access road will be used to both provide access for the construction of temporary emergency works as well as a base upon which to build the emergency works. Through forward planning, when it is known that water must be released from the Skins Lake Spillway, temporary emergency works can be placed upon the permanent access road, and the level of flood protection can be raised to an appropriate level.

The access road and permanent structure have been designed to support a commercially available product known as HESCO bales. The HESCO bale is a relatively lightweight wire mesh basket lined with a geotextile fabric which can be quickly set up and then filled with sand to create a relatively impermeable barrier to flood waters. The HESCO bales are designed to be set up in a continuous fashion to create a linear barrier. Emergency Management BC owns HESCO bales, and lends them out to communities during emergency flood events. In fact, the District of Vanderhoof made use of Emergency Management BC's HESCO bales during the 2007 flood. Alternatively, HESCO bales can be purchased and stored.

When the flood waters have receded, the HESCO bales can be removed with relative ease through the use of a lifting jig. The bales are designed without a bottom so that the sand which had been placed in the bales simply drops out of the bottom. The bales themselves can be stored and re-used in the future, while the sand can be collected and removed from the permanent barrier.

In some areas of Vanderhoof, only low level flood protection works are recommended. In these cases, the ground level is sufficiently high that most homes are not at risk of flooding, and only some homes require localized protection. In other circumstances, there is not the ability to easily access the desired location for the flood protection works, for example, there are areas where the best location for the localized protection is in fully developed backyards. In these circumstances, the use of sandbag dikes is recommended. The locations of sandbag dikes are shown on Figures 1 through 6 in Appendix A for a range of flood levels, while recommended procedures for the construction of sand bag dikes are included in Appendix C. In addition, Appendix C also includes a schedule of quantities for temporary flood protection works (i.e. sand bags, sand volumes and HESCO Bales). These quantities are grouped into two scenarios.

- Sand Bag Options: assumes HESCO bales are not available therefore sand bags will need to be used for all of the protection areas under this plan.
- HESCO Bale Options: assumes HESCO bales are available and will be used for the undeveloped areas as shown in Figures 1 – 6 of Appendix A. This option includes sand bags for the developed areas and in some areas where they are to be stacked on top of HESCO bales to provide further protection.

Quantities for the permanent works are included in Section 5.0 of this report.

4.0 FLOOD PREPARATION AND PLANNING

As noted earlier, the dam and reservoir system and the Skins Lake spillway upstream of Vanderhoof provide the ability to manage the flow of water in the Nechako River, and the potential adverse impact on Vanderhoof as a result of high water levels in the river. In order to manage the impact, and effectively protect property within Vanderhoof, staff of the District of Vanderhoof must work with staff of Rio Tinto Alcan and the Province in order to manage the flood risk in any given year.

These coordination efforts should include close communication with Rio Tinto Alcan in order to understand conditions in the watershed and the potential for high flows in the river. When it becomes clear that high river levels are expected, steps can be taken to protect property to the appropriate level associated with the planned flow rate in the river. It must be recognized that the specific conditions that will result in high water levels in the river can be highly variable. As a result, the specific flood protection response must be geared towards the maximum flow rate that is expected during that particular event based on the rate that Rio Tinto Alcan releases from the Skins Lake Spillway, and the associated and resulting high water level in the District of Vanderhoof.

It must also be noted that the proposed flood preparation and emergency response plan requires the construction of permanent works for access and upon which the temporary emergency works can be constructed. In order to achieve this goal, it will be necessary to both seek funding to construct the proposed permanent works as circumstances permit, and to obtain the consent of the property owners to allow the works to be constructed. This consent must be secured through the provision of a statutory right of way for the express purpose of allowing the works to be constructed, maintained, and used during a high water emergency.

The proposed permanent works can be constructed on a piecemeal basis as funding becomes available. The sequence with which the works are constructed will depend on the amount of funding available, and the willingness of property owners to consent to their construction and provide a permanent right of way for the works.

In addition, due to the proximity of the proposed permanent works to the Nechako River and its riparian area, it is recommended that the options be reviewed with regulatory agencies such as the BC Ministry of Natural Resource Operations, the BC Ministry of Environment and Fisheries and Oceans Canada prior to construction. Any works proposed within 30 m of the Nechako River (or its tributaries) may require applications to the BC Ministry of Natural Resource Operations (under Section 9 of the Water Act) and to Fisheries and Oceans Canada (Project Review Application Form). Also, it is advisable to seek the services of a professional archaeologist on the potential to disturb unknown and/or unrecorded archaeological resources for any areas where excavations are required.

Since the development of this plan is intended to guide the community in managing future flooding situations in a proactive and planned way, it is assumed that the proposed permanent works will be completed outside of an emergency situation. Therefore, the following best management practices should be implemented during construction:

- Vegetation removal should be limited and conducted during the reduced risk window for birds for the Nechako area (August 1 through to April 30).
- Sediment and other deleterious materials should be prevented from entering surface water resources.
- Sedimentation and erosion controls such as silt fencing should be kept on site and used as necessary to minimize sedimentation.
- Equipment used during the construction activities should be clean and in a state of good repair.
- Machinery should not be operated within the wetted perimeter of the Nechako River.
- All equipment units should be supplied with spill kits and each operator will be knowledgeable in its use. Any spill to surface water will be immediately reported to the Provincial Emergency Program 24 hour phone line at 1-800-663-3456.
- Equipment should be inspected for leaks during construction. Leaking equipment should be immediately removed from the site and repaired.
- Re-fuelling of equipment and machinery should be conducted a minimum of 30 m away from any surface water resource including drainage ditches.
- Excavated material and debris should be removed from the site or placed in a stable area above the high water mark as far as possible from the Nechako River.
- Construction activities should be delayed during periods of significant rainfall.
- In the event that flowing water is present in any of the areas where culverts are proposed, the work area should be isolated from all flowing water prior to construction. Fish salvage may also be required.
- Any groundwater that is pumped from excavations should be discharged to a suitable location (i.e. a natural vegetated depression) where the water will infiltrate to ground and not be permitted to enter the Nechako River or its tributaries.
- All disturbed areas outside of the permanent works areas should be re-seeded using an appropriate native seed mix.

Finally, prior to the construction of any permanent works, it will also be necessary for the designer to carry out a final field review and complete the detailed designs of the works. This step is necessary for the following key reasons:

1. The time constraints associated with the preparation of this flood response plan did not permit sufficient time to secure precise alignments for the proposed permanent works with each property owner. As a result, modifications to the proposed alignments may be necessary to better suit the needs of the property owners before consent to construct is given.
2. Similarly, the time constraints and weather conditions did not permit in-field geotechnical investigations. As a result, the designs are based on general rather than specific geotechnical information. Prior to construction of any works, actual field conditions must be investigated to ensure that the ground conditions are suitable to support the permanent structure as proposed, or that the permanent structure must be revised to support the design loads (i.e. heavy equipment and flood water pressure) given actual ground conditions. See Geotechnical report (prepared by AMEC Earth & Environmental) in Appendix D for further discussions pertaining to the design works of this project.
3. To obtain detailed survey information as the current designs are based upon topographic map information with limited accuracy.

5.0 COST ESTIMATES FOR PERMANENT WORKS

In order to facilitate the securing of funding for the permanent portion of the flood protection works, cost estimates have been prepared in 2011 dollars. The estimates are based on the proposed cross section and are broken down by alignment option. The costs include allowances for clearing and grubbing rights of way, stripping and stockpiling unsuitable material, sub-excavation of native material, construction of impermeable portion assuming native material is used, supply & placement of granular structure, and restoration of disturbed areas. Furthermore, the cost estimates include allowances for engineering work (i.e. detailed civil design, geotechnical and topographical survey) related to the finalization of design, and field reviews and coordination of construction activities. The engineering allowance estimates were based on the assumption that the current design is suitable and will not require significant design changes due to unforeseen site conditions.

There will also likely be costs associated with securing Statutory Rights of Way (SRW) on the private property where permanent works are proposed. Those costs, however, are difficult to predict, and can only be firmly established once negotiations with property owners have been carried out. Furthermore, such negotiations are best led by a land agent experienced in assessing the value of land for such purposes. For this study, however, we have included an allowance for land acquisition under the assumption that costs associated with securing the SRW are at most comparable to raw, undeveloped land values. This has been estimated at about $25,000/ha in the areas under consideration.

The cost estimates have been separated into five main segments of proposed permanent works as follows:

- South Alignment Option 1 between Stewart Street and Sandy Beach Road,
- The common segment of the South Alignment between Sandy Beach Road and Victoria Street,
- South Alignment Option 2 between the sewage lagoon berm and Sandy Beach Road,
- North Alignment Option 1, and
- North Alignment Option 2.

5.1 South Alignment Option 1

Item	Unit	Unit Rate	Quantity	Extension
Clear and Grub	m^2	$ 2.00	12,300	$ 24,600.00
Strip and Stockpile Topsoil/Unsuitable	m^3	$ 2.00	1,200	$ 2,400.00
Supply and Compact Low Permeability Fill	m^3	$ 20.00	3,900	$ 78,000.00
Supply and Compact SGSB	m^3	$ 40.00	4,300	$ 172,000.00
Supply and Compact Base Course	m^3	$ 70.00	790	$ 55,300.00
Ditch	m	$ 10.00	880	$ 8,800.00
Restoration (Replace Topsoil and Seed)	m^2	$ 5.00	5,700	$ 28,500.00
Subtotal (rounded)				**$ 370,000.00**
Contingency Allowance @ 25% (rounded)				$ 93,000.00
Subtotal (rounded)				**$ 463,000.00**
Engineering @ 10% (rounded)				$ 46,000.00
SRW Acquisition Allowance	ha	$ 25,000	1.3	$ 32,500.00
Total (rounded)				**$ 541,500.00**

5.2 South Alignment Common Segment

Item	Unit	Unit Rate	Quantity	Extension
Clear and Grub	m^2	$ 2.00	8,000	$ 16,000.00
Strip and Stockpile Topsoil/Unsuitable	m^3	$ 2.00	800	$ 1,600.00
Supply and Compact Low Permeability Fill	m^3	$ 20.00	2,600	$ 52,000.00
Supply and Compact SGSB	m^3	$ 40.00	2,900	$ 116,000.00
Supply and Compact Base Course	m^3	$ 70.00	500	$ 35,000.00
Ditch	m	$ 10.00	550	$ 5,500.00
Restoration (Replace Topsoil and Seed)	m^2	$ 5.00	4,000	$ 20,000.00
450 mm CMP Culvert	Ls	$ 8,000	1	$ 8,000.00
Subtotal (rounded)				**$ 254,100.00**
Contingency Allowance @ 25% (rounded)				$ 63,500.00
Subtotal (rounded)				**$ 317,600.00**
Engineering @ 10% (rounded)				$ 32,000.00
SRW Acquisition Allowance	ha	$ 25,000	0.8	$ 20,000.00
Total (rounded)				**$ 370,000.00**

5.3 South Alignment Option 2

Item	Unit	Unit Rate	Quantity	Extension
Clear and Grub	m^2	$ 2.00	7,700	$ 15,400.00
Strip and Stockpile Topsoil/Unsuitable	m^3	$ 2.00	800	$ 1,600.00
Supply and Compact Low Permeability Fill	m^3	$ 20.00	2,500	$ 50,000.00
Supply and Compact SGSB	m^3	$ 40.00	2,700	$ 108,000.00
Supply and Compact Base Course	m^3	$ 70.00	500	$ 35,000.00
Ditch	m	$ 10.00	550	$ 5,500.00
Restoration (Replace Topsoil and Seed)	m^2	$ 5.00	3,600	$ 18,000.00
900 mm CMP Culvert	Ls	$10,000	1	$ 10,000.00
Subtotal (rounded)				**$ 244,000.00**
Contingency Allowance @ 25% (rounded)				$ 61,000.00
Subtotal (rounded)				**$ 305,000.00**
Engineering @ 10% (rounded)				$ 30,500.00
SRW Acquisition Allowance	ha	$ 25,000	0.95	$ 24,000.00
Total (rounded)				**$ 360,000.00**

5.4 North Alignment Option 1

Item	Unit	Unit Rate	Quantity	Extension
Clear and Grub	m^2	$ 2.00	7,400	$ 14,800.00
Strip and Stockpile Topsoil/Unsuitable	m^3	$ 2.00	700	$ 1,400.00
Supply and Compact Low Permeability Fill	m^3	$ 20.00	2,400	$ 48,000.00
Supply and Compact SGSB	m^3	$ 40.00	2,600	$ 104,000.00
Supply and Compact Base Course	m^3	$ 70.00	480	$ 33,600.00
Ditch	m	$ 10.00	530	$ 5,300.00
Restoration (Replace Topsoil and Seed)	m^2	$ 5.00	3,400	$ 17,000.00
900 mm Culvert	LS	$10,000	1	$ 10,000.00
Subtotal (rounded)				**$ 234,000.00**
Contingency Allowance @ 25% (rounded)				$ 59,000.00
Subtotal (rounded)				**$ 293,000.00**
Engineering @ 10% (rounded)				$ 29,000.00
SRW Acquisition Allowance	ha	$ 25,000	0.85	$ 21,500.00
Total (rounded)				**$ 344,000.00**

5.5 North Alignment Option 2

Item	Unit	Unit Rate	Quantity	Extension
Clear and Grub	m^2	$ 2.00	8,000	$ 16,000.00
Strip and Stockpile Topsoil/Unsuitable	m^3	$ 2.00	800	$ 1,600.00
Supply and Compact Low Permeability Fill	m^3	$ 20.00	2,600	$ 52,000.00
Supply and Compact SGSB	m3	$ 40.00	2,800	$ 112,000.00
Supply and Compact Base Course	m^3	$ 70.00	510	$ 35,700.00
Ditch	m	$ 10.00	570	$ 5,700.00
Restoration (Replace Topsoil and Seed)	m^2	$ 5.00	3,700	$ 18,500.00
Subtotal (rounded)				**$ 242,000.00**
Contingency Allowance @ 25% (rounded)				$ 61,000.00
Subtotal (rounded)				**$ 303,000.00**
Engineering @ 10% (rounded)				$ 30,000.00
SRW Acquisition Allowance	ha	$ 25,000	0.85	$ 21,500.00
Total (rounded)				**$ 355,000.00**

6.0 OTHER MEASURES

In the event of a flood, there are a number of other measures which must be undertaken to protect the areas at risk.

First, there are a number of openings that must be closed to prevent flood waters from entering the area protected. In particular, special attention should be given to storm sewer outfalls and culverts. See Appendix A – Floodplain Figures for location of storm sewer outfalls and culverts. This infrastructure is normally directly connected to the river, and represents significant sources of potential back flow into the protected areas. In advance of the flood event, steps must be taken to block outfalls from storm sewers and culverts. This can be done through the use of sandbags at both inlets and outlets, as well as through the use of air filled sewer plugs.

Similar to culverts and storm sewers, particularly during extreme flood events, sanitary sewers can become a source of back up into buildings. This can happen because some sanitary sewer manholes are open to the flood waters, which then flow into the sewers and overwhelm the capacity of the sewers to carry the water away. In this case, the manholes can be protected with sandbags to prevent water from entering the openings. See Appendix A – Floodplain Figures for location of sanitary manholes prone to the various flood events. Homeowners can further protect themselves from the possibility of sewer backup into their basements or crawl spaces by installing a back flow preventer, or in an emergency temporarily plugging their main sewer drain with an air filled plug.

In some cases, the ground can become saturated and the groundwater level increased because of the elevated flood waters. As a result, the risk increases for the basements of some houses to become flooded. Sump pumps can be used to keep ground water levels down around houses, but the discharge from sump pumps is often to the ground surface outside the house, and this can often lead to a closed loop of sorts in which the sump pump water is pumped outside only to infiltrate into the ground and affect the building basement again. An alternative, in such cases, is to pump the groundwater to the storm sewer system, if available. In any case, in advance of the flood event, homeowners should be advised to check that their sump pumps are operating properly.

In circumstances when the outlets of culverts and storm sewers are plugged, it is usually necessary to plan for the provision of major pumps to remove water from either the storm sewer or the culvert inlet. Furthermore, seepage (groundwater) flows are expected to be a concern during future flood events as they were during the 2007 flood. Thus, plans must be made to ensure that sufficient pumping capacity is available to remove accumulations of local drainage and seepage flows from these locations, and pump this water over the emergency dike works. Specific pumping requirements were not estimated under this plan due to the high variability and uncertainty of the soil / ground water / rainfall dynamics and the resulting seepage flows.

However, mobile pump stations such as those used during the 2007 flood (Figure 2) should be used during future flood events. Proposed mobile pump station locations are identified on Figures 2-6 in Appendix A.

In all of these cases, homeowners should be advised to take the precautionary step of moving all valuables from the portions of their homes that are at risk of flooding to areas that are above the potential height of the flood waters.

Finally, during a high water event, and following the declaration of a state of emergency or a state of local emergency, District of Vanderhoof staff members, and others appointed by the District, have considerable emergency powers to all reasonable things necessary to protect life and property from the adverse impacts of flood waters. These emergency powers are granted under the *Emergency Program Act*. Familiarity with that act is recommended before exercising any special powers.

Figure 2 – Temporary Mobile Pump Station

appendix a

District of Vanderhoof

Flood Protection Plan

Floodplain Figures

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FLOOD PROTECTION PLAN

DATE: MARCH 2011

DISTRICT OF VANDERHOOF

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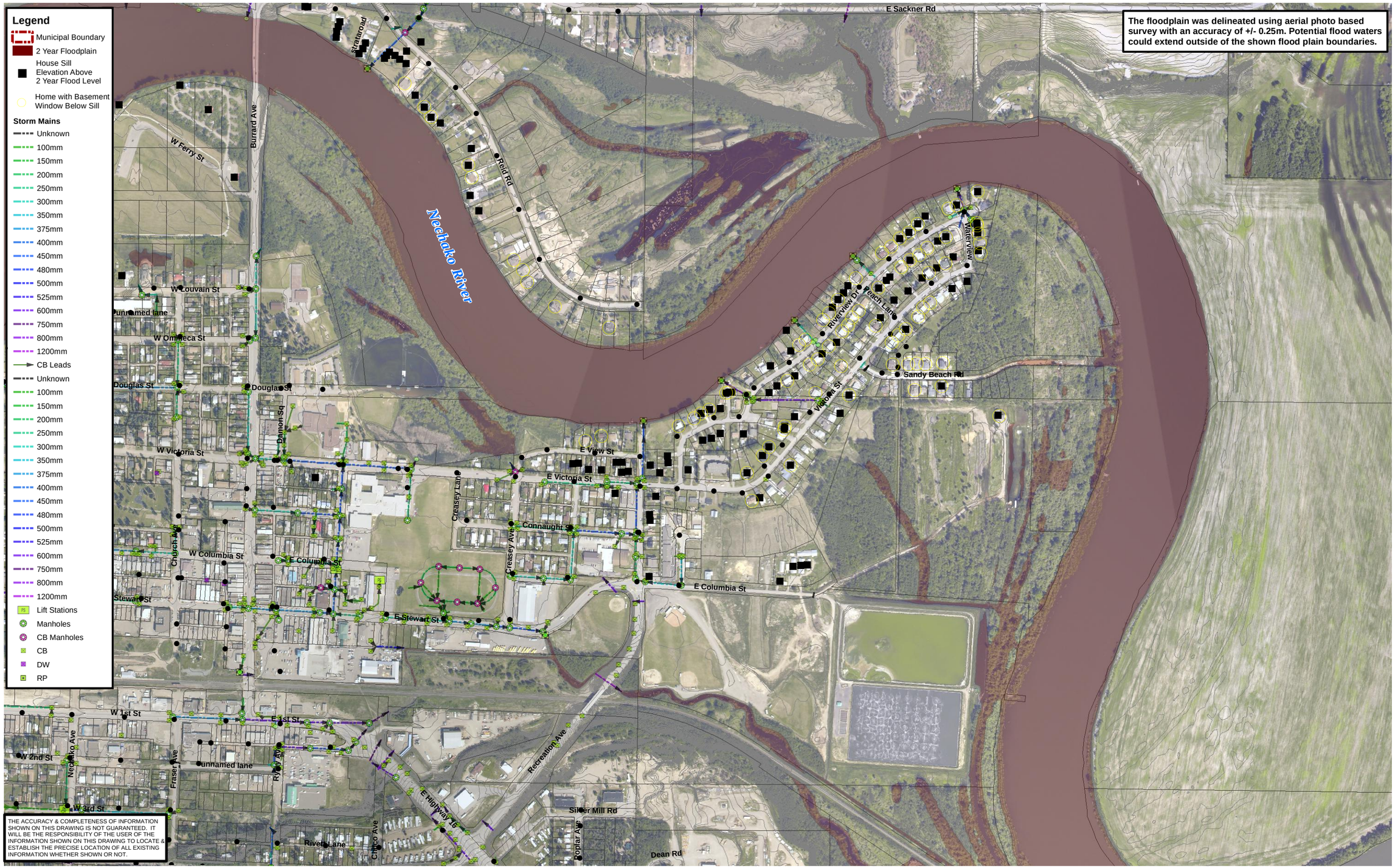

2 Year Floodplain
Elev: 635.70m
Flow Rate: 400m^3/s

2 YEAR FLOODPLAIN

FIGURE

1

URBANSYSTEMS.

FLOOD PROTECTION PLAN

DATE: MARCH 2011

DISTRICT OF VANDERHOOF

1:7,500

10 Year Floodplain
Elev: 636.92m
Flow Rate: 620m³/s

The floodplain was delineated using aerial photo based survey with an accuracy of +/- 0.25m. Potential flood waters could extend outside of the shown flood plain boundaries.

Legend

- Municipal Boundary
- 10 Year Floodplain
- House Sill Elevation Above 10 Year Flood Level
- Manhole Elevation Below 10 Year Flood Level
- Home with Basement Window Below Sill
- HESCO Bale Alignment
- Sandbag Alignment
- Proposed Temporary Pump Station Location

Storm Mains

- Unknown
- 100mm
- 150mm
- 200mm
- 250mm
- 300mm
- 350mm
- 375mm
- 400mm
- 450mm
- 480mm
- 500mm
- 525mm
- 600mm
- 750mm
- 800mm
- 1200mm
- CB Leads
- Unknown
- 100mm
- 150mm
- 200mm
- 250mm
- 300mm
- 350mm
- 375mm
- 400mm
- 450mm
- 480mm
- 500mm
- 525mm
- 600mm
- 750mm
- 800mm
- 1200mm
- Lift Stations
- Manholes
- CB Manholes
- CB
- DW
- RP

NORTH SHORE HESCO BALE ALIGNMENT OPTION 1

NORTH SHORE HESCO BALE ALIGNMENT OPTION 2

PROPOSED ACCESS ROAD

PROPOSED ACCESS ROAD

SOUTH SHORE COMMON SEGMENT

SOUTH SHORE HESCO BALE ALIGNMENT 1

SOUTH SHORE HESCO BALE ALIGNMENT 2

SOUTH SHORE RAILWAY SEGMENT

Nechako River

W Loop Rd
Northside Rd
Stratford
E Redfern Dr
Northside Rd
E Sackner Rd
Burrard Ave
W Ferry St
Reid Rd
Waterview
Riverview Dr
Peach Lane
Sandy Beach Rd
Victoria St
W Columbia St
W Douglas St
E Douglas St
Taylor Ave
Damon St
W Victoria St
Lamprit Ave
E View St
E Victoria St
Creasey Lane
Creasey Ave
Connaught St
E Columbia St
Church Ave
Campbell Ave
Lundin Dr
W Stewart St
E Stewart St
W Louvain St
unnamed lane
W Omineca St
W 1st St
E 1st St
W 2nd St
Nechako Ave
Fraser Ave
unnamed lane
RV Ave
W 3rd St
E Highway 16
Recreation Ave
Silver Mill Rd

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10 YEAR FLOODPLAIN

FIGURE

2

URBANSYSTEMS.

FLOOD PROTECTION PLAN

DATE: MARCH 2011

DISTRICT OF VANDERHOOF

1:7,500

20 Year Floodplain
Elev: 637.19m
Flow Rate: 700m³/s

The floodplain was delineated using aerial photo based survey with an accuracy of +/- 0.25m. Potential flood waters could extend outside of the shown flood plain boundaries.

NORTH SHORE HESCO BALE ALIGNMENT OPTION 1

NORTH SHORE HESCO BALE ALIGNMENT OPTION 2

PROPOSED ACCESS ROAD

PROPOSED ACCESS ROAD

SOUTH SHORE COMMON SEGMENT

SOUTH SHORE HESCO BALE ALIGNMENT 1

SOUTH SHORE HESCO BALE ALIGNMENT 2

SOUTH SHORE RAILWAY SEGMENT

Nechako River

W Loop Rd
Northside Rd
Strawroad
E Redfern Dr
Northside Rd
E Sackner Rd
Reid Rd
Burrard Ave
W Ferry St
W Louvain St
unnamed lane
W Omineca St
W Douglas St
Douglas St
Taylor Ave
Dennon Sq
W Victoria St
Lamplit Ave
Lumdin Dr
Campbell Ave
Church Ave
W Columbia St
E Columbia St
W Stewart St
E Stewart St
Creasey Lane
E View St
E Victoria St
Connaught St
Creasey Ave
W 1st St
E 1st St
W 2nd St
W 3rd St
Clarke Ave
Nechako Ave
Fraser Ave
unnamed lane
Ryan Ave
E Highway 16
Recreation Ave
Silver Mill Rd
Riverview Dr
Peach Lane
Waterview
Victoria St
Sandy Beach Rd

Legend

- Municipal Boundary
- 20 Year Floodplain
- House Sill Elevation Above 20 Year Flood Level
- Manhole Elevation Below 20 Year Flood Level
- Home with Basement Window Below Sill
- HESCO Bale Alignment
- Sandbag Alignment
- Proposed Temporary Pump Station Location

Storm Mains

- Unknown
- 100mm
- 150mm
- 200mm
- 250mm
- 300mm
- 350mm
- 375mm
- 400mm
- 450mm
- 480mm
- 500mm
- 525mm
- 600mm
- 750mm
- 800mm
- 1200mm
- CB Leads
- Unknown
- 100mm
- 150mm
- 200mm
- 250mm
- 300mm
- 350mm
- 375mm
- 400mm
- 450mm
- 480mm
- 500mm
- 525mm
- 600mm
- 750mm
- 800mm
- 1200mm
- Lift Stations
- Manholes
- CB Manholes
- CB
- DW
- RP

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20 YEAR FLOODPLAIN

FIGURE 3

URBANSYSTEMS.

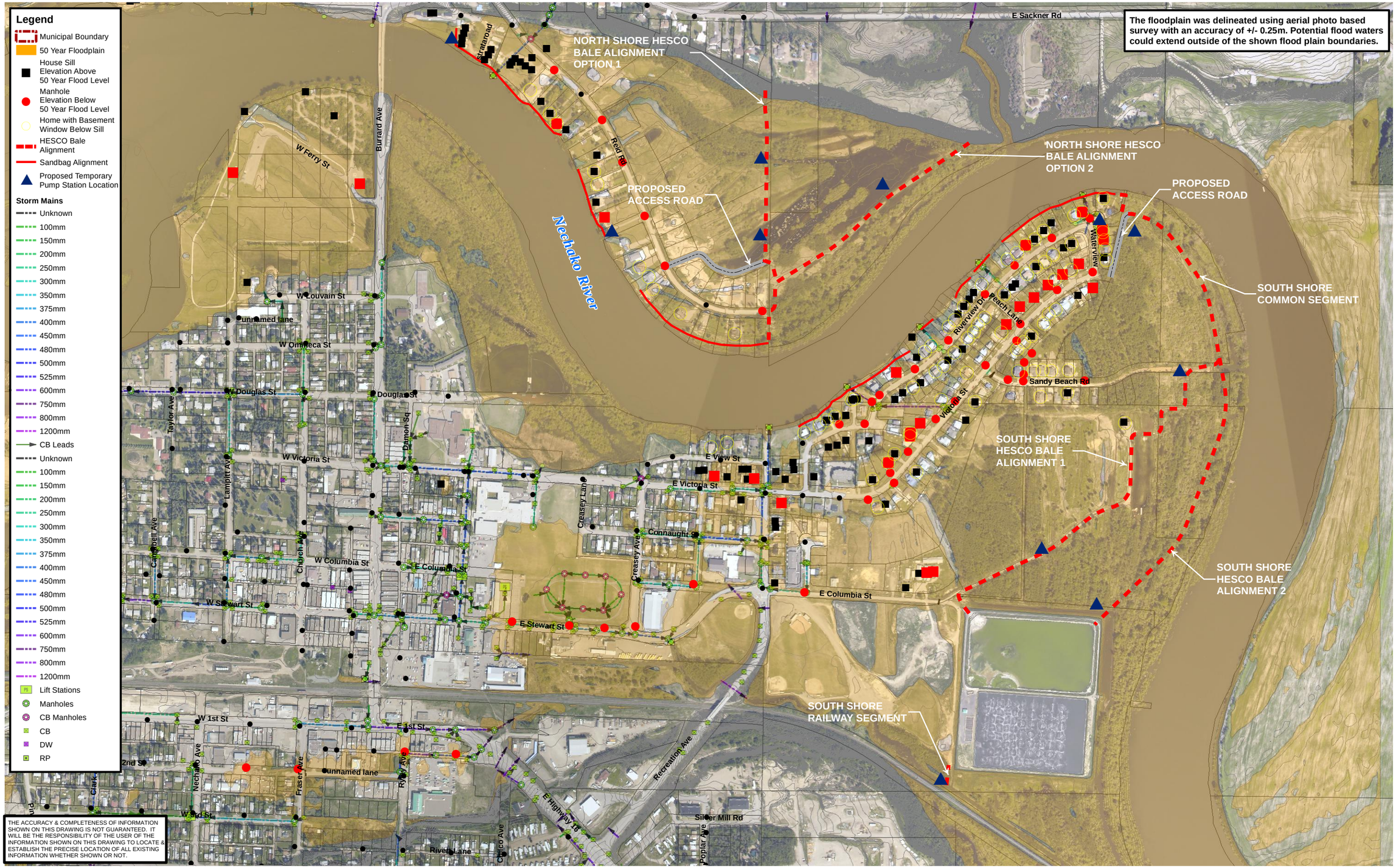
FLOOD PROTECTION PLAN

DATE: MARCH 2011

DISTRICT OF VANDERHOOF

1:7,500

50 Year Floodplain
Elev: 637.55m
Flow Rate: 810m^3/s



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50 YEAR FLOODPLAIN

FIGURE

4

URBANSYSTEMS.

FLOOD PROTECTION PLAN

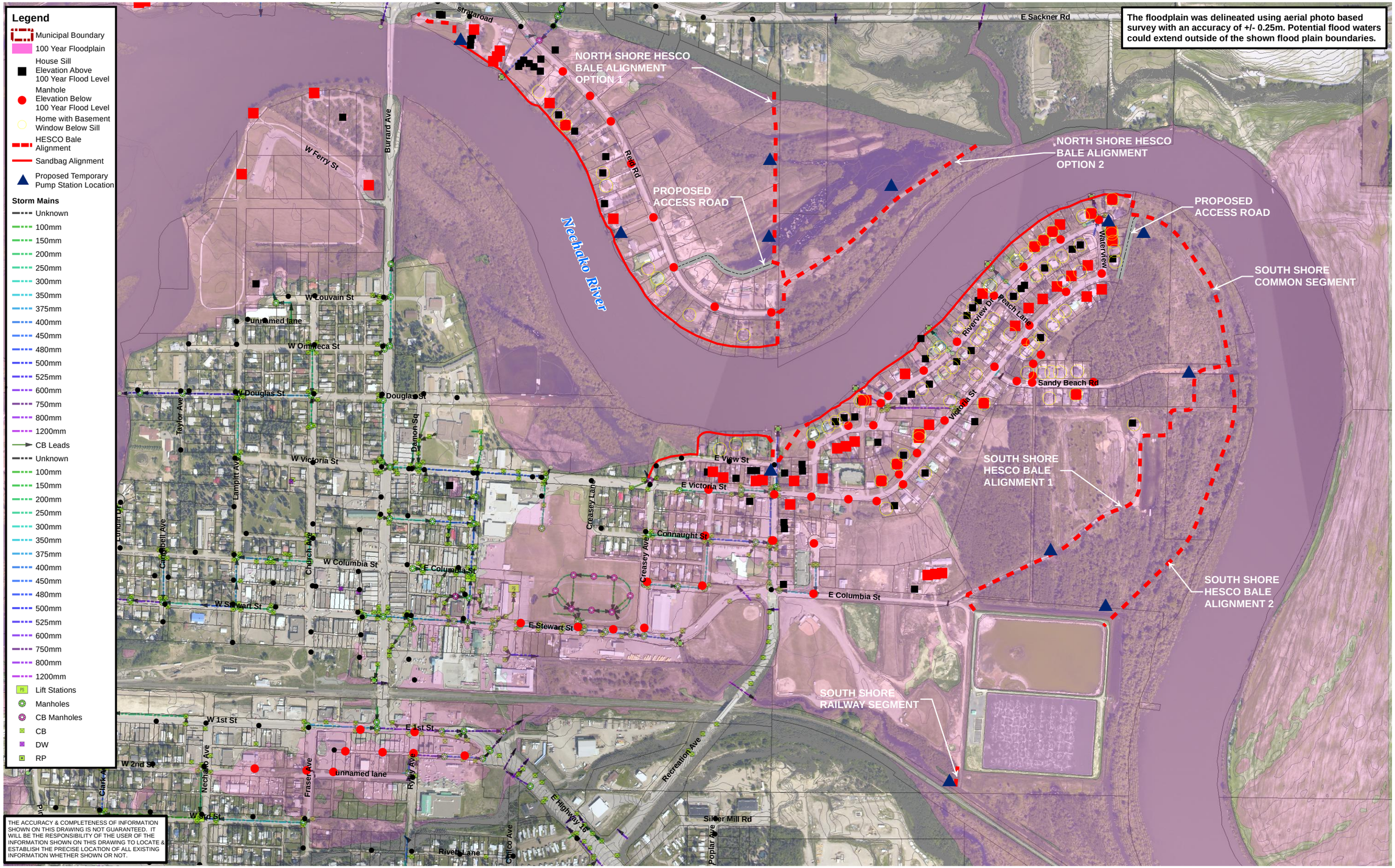
DATE: MARCH 2011

DISTRICT OF VANDERHOOF

1:7,500

100 Year Floodplain
Elev: 637.85m
Flow Rate: 890m^3/s

The floodplain was delineated using aerial photo based survey with an accuracy of +/- 0.25m. Potential flood waters could extend outside of the shown flood plain boundaries.



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100 YEAR FLOODPLAIN

FIGURE

5

URBANSYSTEMS.

FLOOD PROTECTION PLAN

DATE: MARCH 2011

DISTRICT OF VANDERHOOF

1:7,500

200 Year Floodplain
Elev: 638.19m
Flow Rate: 964m³/s

The floodplain was delineated using aerial photo based survey with an accuracy of +/- 0.25m. Potential flood waters could extend outside of the shown flood plain boundaries.

Legend

- Municipal Boundary
- 200 Year Floodplain
- House Sill Elevation Above 200 Year Flood Level
- Manhole Elevation Below 200 Year Flood Level
- Home with Basement Window Below Sill
- HESCO Bale Alignment
- Sandbag Alignment
- Proposed Temporary Pump Station Location

Storm Mains

- Unknown
- 100mm
- 150mm
- 200mm
- 250mm
- 300mm
- 350mm
- 375mm
- 400mm
- 450mm
- 480mm
- 500mm
- 525mm
- 600mm
- 750mm
- 800mm
- 1200mm
- CB Leads
- Unknown
- 100mm
- 150mm
- 200mm
- 250mm
- 300mm
- 350mm
- 375mm
- 400mm
- 450mm
- 480mm
- 500mm
- 525mm
- 600mm
- 750mm
- 800mm
- 1200mm
- Lift Stations
- Manholes
- CB Manholes
- CB
- DW
- RP

NORTH SHORE HESCO BALE ALIGNMENT OPTION 1

NORTH SHORE HESCO BALE ALIGNMENT OPTION 2

PROPOSED ACCESS ROAD

PROPOSED ACCESS ROAD

SOUTH SHORE COMMON SEGMENT

SOUTH SHORE HESCO BALE ALIGNMENT 1

SOUTH SHORE HESCO BALE ALIGNMENT 2

SOUTH SHORE RAILWAY SEGMENT

Nechako River

Northside Rd

Stratford Rd

E Redfern Dr

E Sackner Rd

Reid Rd

Burrard Ave

W Ferry St

W Louvain St

Unnamed lane

W Omineca St

W Douglas St

Douglas St

Taylor Ave

Lampitt Ave

Lundin Dr

Campbell Ave

Church Ave

Damon Sq

W Victoria St

W Columbia St

E Columbia St

W Stewart St

E Stewart St

W 1st St

E 1st St

W 2nd St

Clarke Ave

Nechako Ave

Fraser Ave

unnamed lane

Riley Ave

W 3rd St

E Highway 16

Silver Mill Rd

Recreation Ave

Creasey Lane

Creasey Ave

E View St

E Victoria St

Connaught St

E Columbia St

Waterview

Riverview Dr

Peach Lane

Victoria St

Sandy Beach Rd

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200 YEAR FLOODPLAIN

FIGURE

6

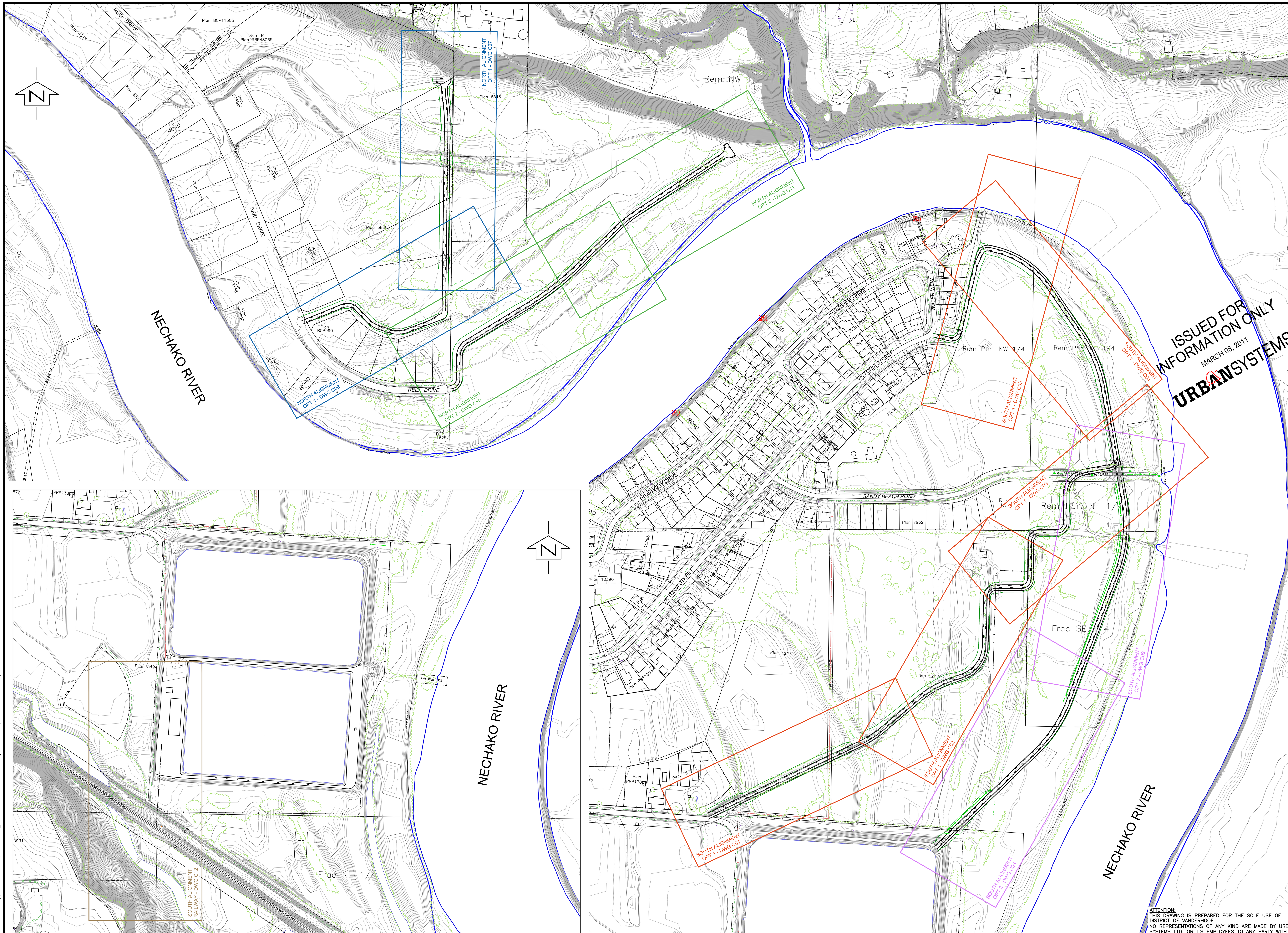
appendix b

District of Vanderhoof

Flood Protection Plan

Proposed Permanent Works Design Drawings

URBANSYSTEMS.



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DESCRIPTION	DATE (yy/mm/dd)
FOR PRELIMINARY	–
FOR APPROVAL	–
FOR TENDER	–
FOR CONSTRUCTION	–
FOR RECORD	–
FOR ARCHIVE	–

LEGEND

EXISTING

- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
- DRAINAGE FLOW
- LAMP STANDARD
- HYDRO POLE
- MAJOR DRAINAGE FLOW
- 684.0 PREDEVELOPMENT CONTOURS

PROPOSED

- EDGE OF GRAVEL
- TOP OF LOW PERMEABILITY MATERIAL
- TOP/TOE OF SLOPE
- DITCH
- 200 YEAR FLOOD ELEVATION 638.20
- 100 YEAR FLOOD ELEVATION 637.85
- 50 YEAR FLOOD ELEVATION 637.55
- 20 YEAR FLOOD ELEVATION 637.20
- 10 YEAR FLOOD ELEVATION 636.90

REVISIONS

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VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

KEYPLAN

PROJECT No. 0613.0046.01

SHEET 1 OF 14

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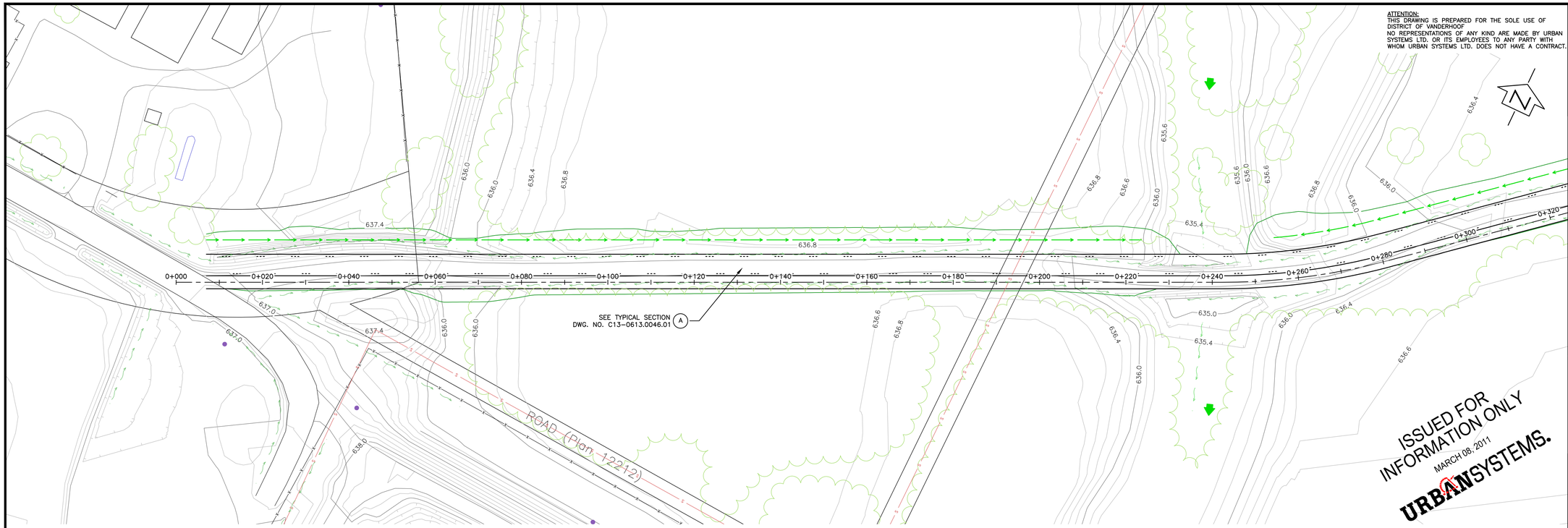
DRAWING No. C00-0613.0046.01 R 0



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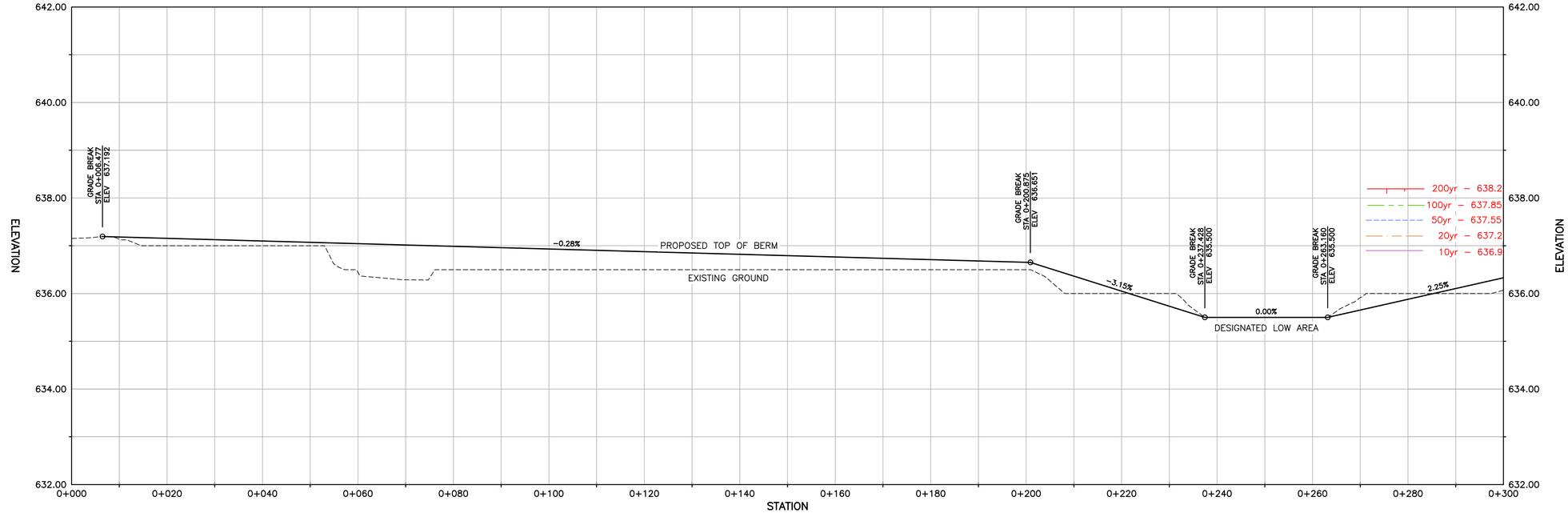
3. FINAL CONFIGURATION AND LOCATION IN FIELD TO BE CONFIRMED WITH PROPERTY OWNER PRIOR TO CONSTRUCTION.
4. THIS STRUCTURE IS NOT A FLOOD BARRIER
5. DITCH GRADES MATCH ROAD PROFILE



	0+000	0+020	0+040	0+060	0+080	0+100	0+120	0+140	0+160	0+180	0+200	0+220	0+240	0+260	0+280	0+300
EXISTING ELEVATIONS	637.14	637.00	637.00	637.00	637.00	636.45	636.29	636.50	636.50	636.50	636.50	636.50	636.50	636.50	636.00	636.00
BERM ELEVATIONS	637.182	637.155	637.127	637.099	637.071	637.043	637.016	636.988	636.960	636.932	636.904	636.876	636.849	636.821	636.793	636.765
	636.50	636.50	636.50	636.50	636.50	636.50	636.50	636.50	636.50	636.50	636.50	636.00	636.00	636.00	635.92	636.00
	636.737	636.710	636.682	636.654	636.364	636.049	635.734	635.500	635.500	635.500	635.654	635.879	636.104			

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FOR TENDER	–
FOR CONSTRUCTION	–
FOR RECORD	–
FOR ARCHIVE	–

LEGEND

EXISTING
- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
- DRAINAGE FLOW
- LAMP STANDARD
- HYDRO POLE
- 684.0 PREDEVELOPMENT CONTOURS
- MAJOR DRAINAGE FLOW

PROPOSED
- EDGE OF GRAVEL
- TOP OF LOW PERMEABILITY MATERIAL
- TOP/TOE OF SLOPE
- DITCH
- 200 YEAR FLOOD ELEVATION 638.20
- 100 YEAR FLOOD ELEVATION 637.85
- 50 YEAR FLOOD ELEVATION 637.55
- 20 YEAR FLOOD ELEVATION 637.20
- 10 YEAR FLOOD ELEVATION 636.90

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REVISIONS

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P. ENG. – DATE YY-MM-DD

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URBANSYSTEMS.

VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

SOUTH ALIGNMENT OPTION 1 PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 2 OF 14

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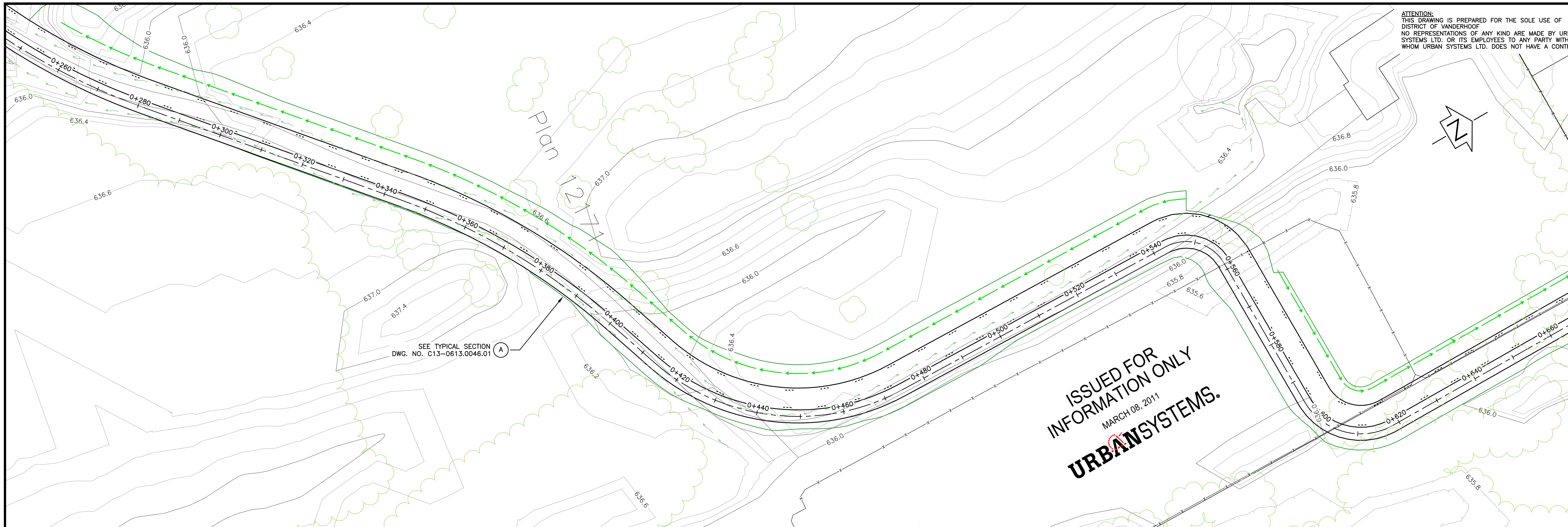

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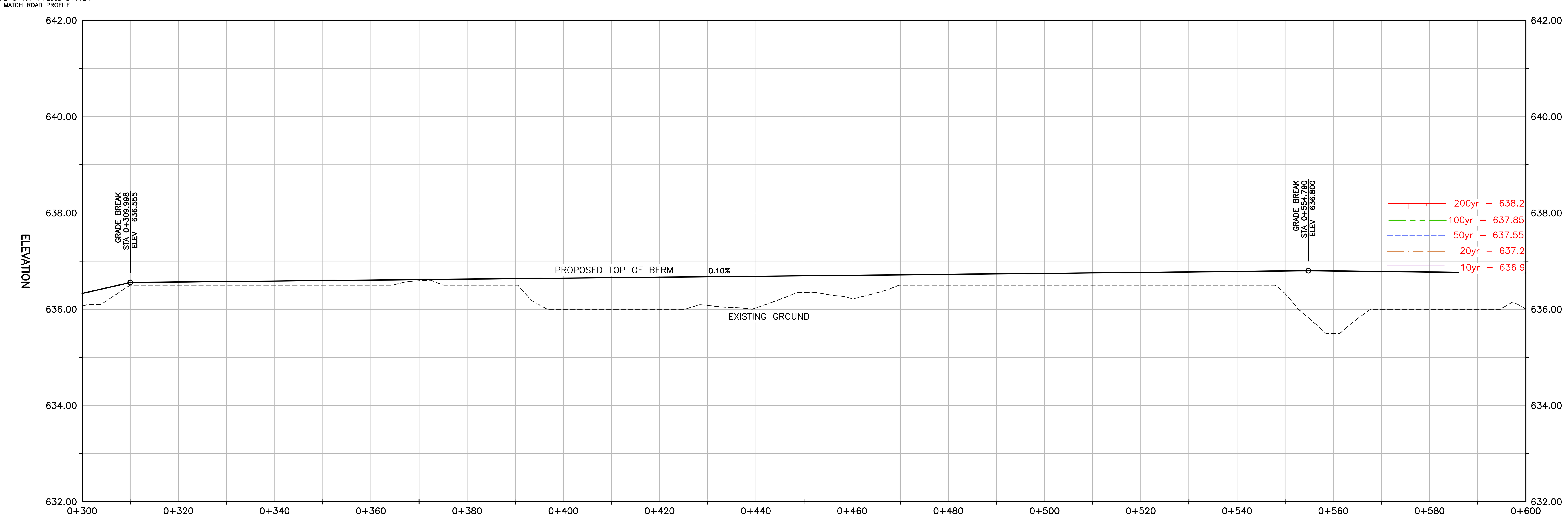
3. FINAL CONFIGURATION AND LOCATION IN FIELD TO BE CONFIRMED WITH PROPERTY OWNER PRIOR TO CONSTRUCTION.
4. THIS STRUCTURE IS NOT A FLOOD BARRIER
5. DITCH GRADES MATCH ROAD PROFILE



EXISTING ELEVATIONS	636.50	636.50	636.50	636.50	636.50	636.50	636.59	636.50	636.50	636.00	636.00	636.00	636.08	636.03	636.35
BERM ELEVATIONS	636.555	636.565	636.575	636.585	636.595	636.605	636.615	636.625	636.635	636.645	636.655	636.665	636.675	636.685	636.695

EXISTING ELEVATIONS	636.22	636.50	636.50	636.50	636.50	636.50	636.50	636.50	636.50	636.32	635.50	636.00	636.00	636.00
BERM ELEVATIONS	636.705	636.715	636.725	636.735	636.745	636.755	636.765	636.775	636.785	636.795	636.795	636.785	636.775	636.765

ISSUES

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FOR TENDER	–
FOR CONSTRUCTION	–
FOR RECORD	–
FOR ARCHIVE	–

LEGEND

EXISTING
- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
- DRAINAGE FLOW
- LAMP STANDARD
- HYDRO POLE
- MAJOR DRAINAGE FLOW
- PREDEVELOPMENT CONTOURS

PROPOSED
- EDGE OF GRAVEL
- TOP OF LOW PERMEABILITY MATERIAL
- TOP/TOE OF SLOPE
- DITCH
- 200 YEAR FLOOD ELEVATION 638.20
- 100 YEAR FLOOD ELEVATION 637.85
- 50 YEAR FLOOD ELEVATION 637.55
- 20 YEAR FLOOD ELEVATION 637.20
- 10 YEAR FLOOD ELEVATION 636.90

REVISIONS

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URBANSYSTEMS.

VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

SOUTH ALIGNMENT OPTION 1 PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 3 OF 14

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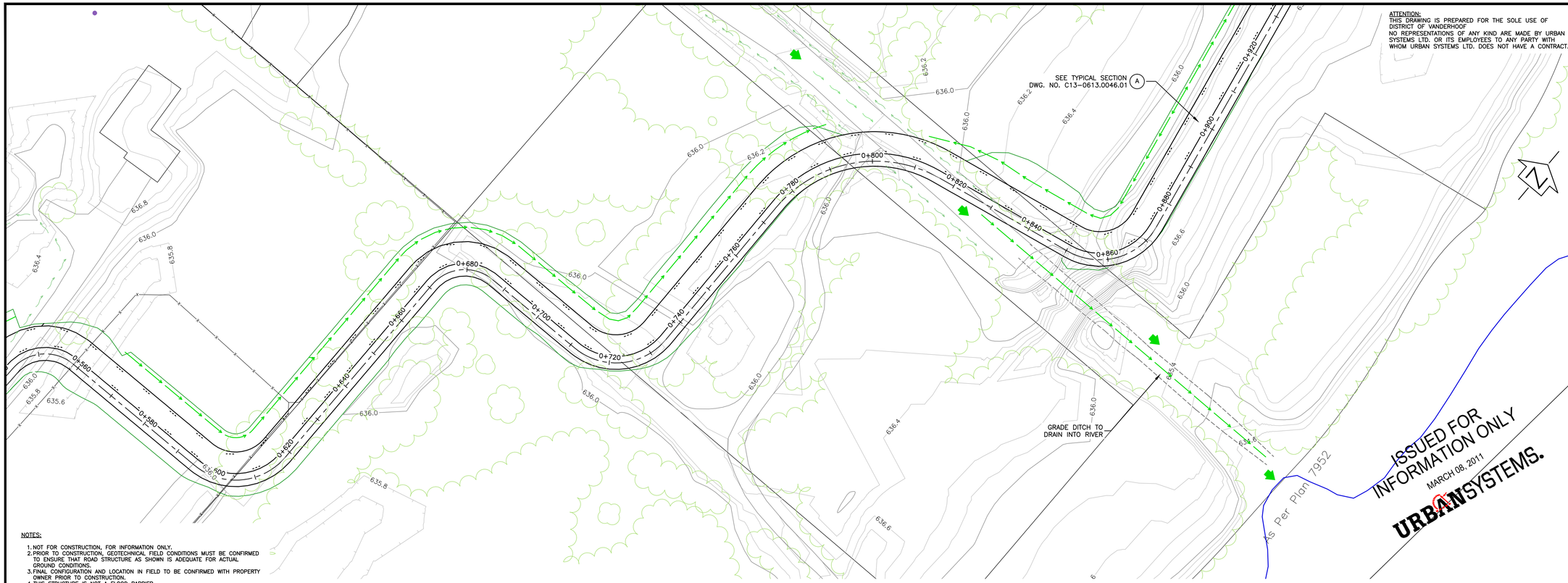

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MARCH 08, 2011
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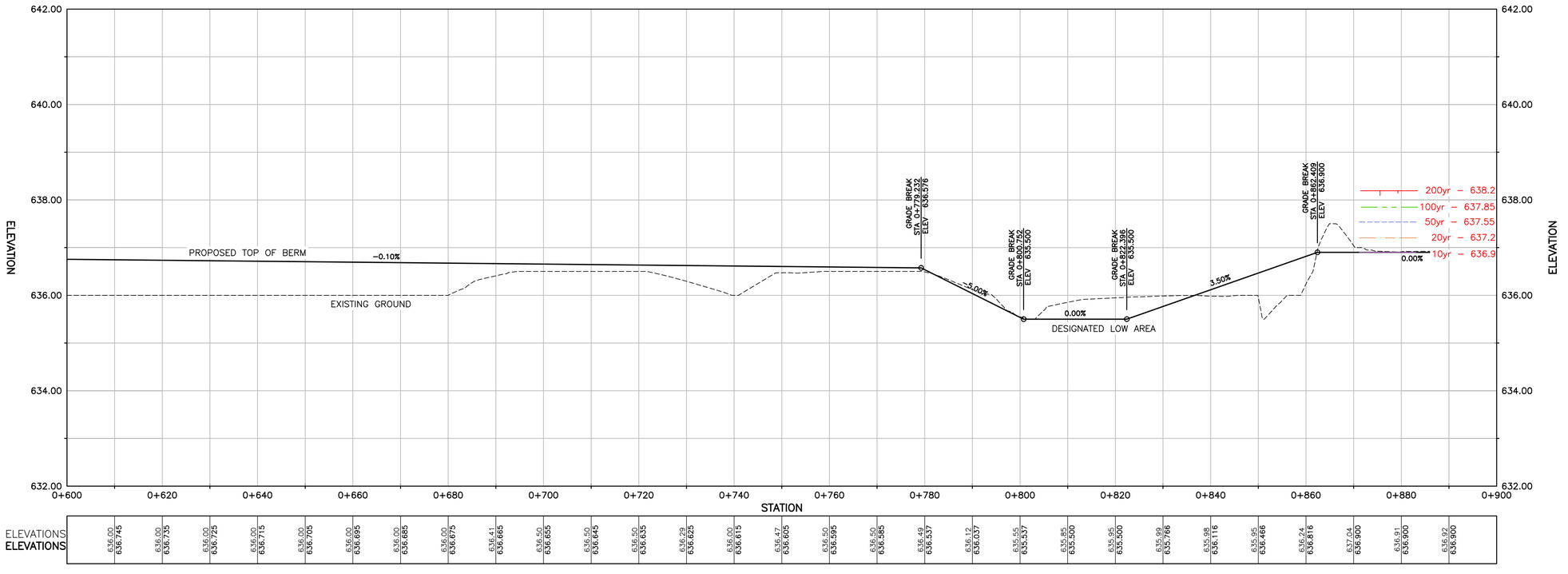
3. FINAL CONFIGURATION AND LOCATION IN FIELD TO BE CONFIRMED WITH PROPERTY OWNER PRIOR TO CONSTRUCTION.
4. THIS STRUCTURE IS NOT A FLOOD BARRIER
5. DITCH GRADES MATCH ROAD PROFILE



EXISTING ELEVATIONS	636.00	636.00	636.00	636.00	636.00	636.00	636.00	636.00	636.41	636.50	636.50	636.50	636.29	636.00	636.47	636.50	636.50	636.49	636.12	635.55	635.85	635.95	635.99	635.98	635.95	636.24	637.04	636.91	636.92
BERM ELEVATIONS	636.745	636.735	636.725	636.715	636.705	636.695	636.685	636.675	636.665	636.655	636.645	636.635	636.625	636.615	636.605	636.595	636.585	636.537	636.037	635.537	635.500	635.500	635.766	636.116	636.466	636.816	636.900	636.900	636.900

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1	–	–	–	–

ISSUES

DESCRIPTION	DATE (yy/mm/da)
FOR PRELIMINARY	–
FOR APPROVAL	–
FOR TENDER	–
FOR CONSTRUCTION	–
FOR RECORD	–
FOR ARCHIVE	–

LEGEND

EXISTING
- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
- DRAINAGE FLOW
- LAMP STANDARD
- HYDRO POLE
- 684.0 PREDEVELOPMENT CONTOURS
- MAJOR DRAINAGE FLOW

PROPOSED
- EDGE OF GRAVEL
- TOP OF LOW PERMEABILITY MATERIAL
- TOP/TOE OF SLOPE
- DITCH
- 200 YEAR FLOOD ELEVATION 638.20
- 100 YEAR FLOOD ELEVATION 637.85
- 50 YEAR FLOOD ELEVATION 637.55
- 20 YEAR FLOOD ELEVATION 637.20
- 10 YEAR FLOOD ELEVATION 636.90

REVISIONS

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DATE	11-02-25
CHK.	CG

P. ENG. – DATE YY-MM-DD

SCALE H 1:500
V 1:50

URBANSYSTEMS.
VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

SOUTH ALIGNMENT OPTION 1 PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 4 OF 14

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DESTROY ALL PRINTS PRIOR TO R 0

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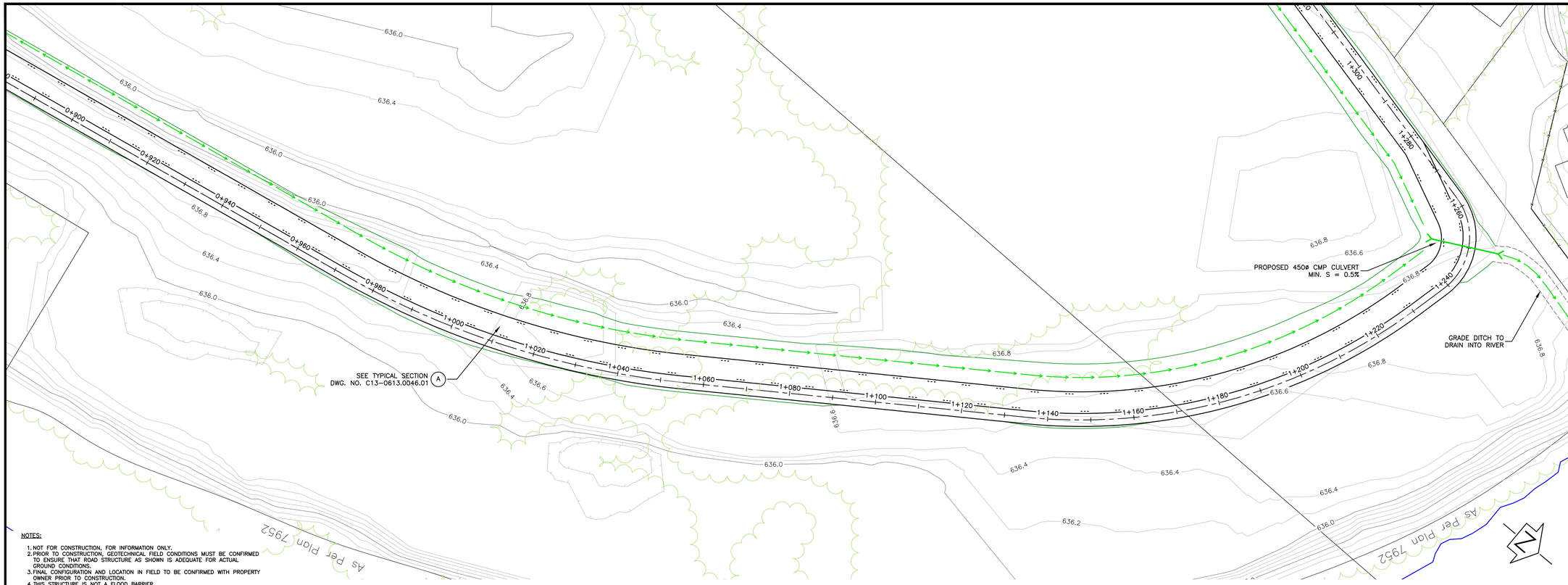

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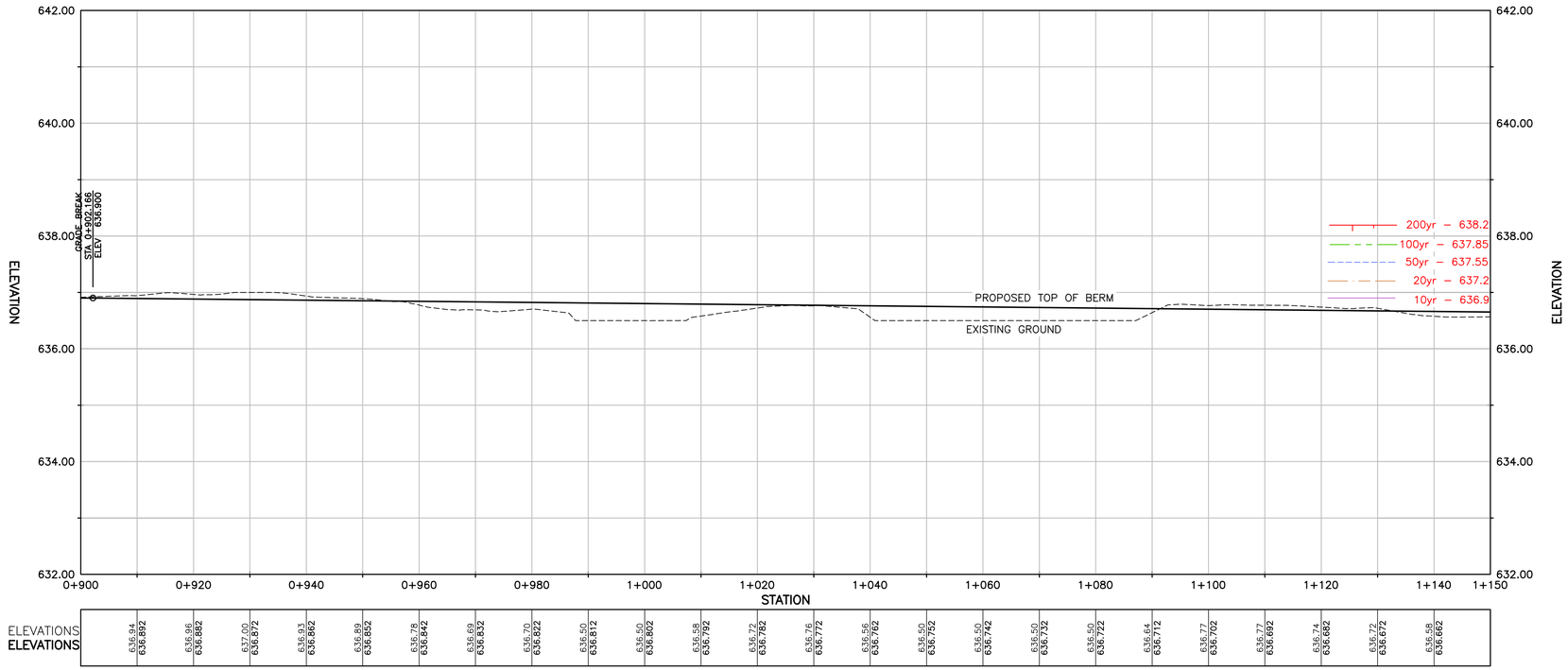
4. THIS STRUCTURE IS NOT A FLOOD BARRIER
5. DITCH GRADES MATCH ROAD PROFILE



	EXISTING ELEVATIONS	636.94	636.96	637.00	636.93	636.89	636.78	636.69	636.70	636.50	636.80	636.58	636.72	636.76	636.56	636.50	636.50	636.50	636.50	636.64	636.77	636.77	636.74	636.72	636.58
	BERM ELEVATIONS	636.892	636.882	636.872	636.862	636.852	636.842	636.832	636.822	636.812	636.802	636.792	636.782	636.772	636.762	636.752	636.742	636.732	636.722	636.712	636.702	636.692	636.682	636.672	636.662

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MARCH 08, 2011
URBANSYSTEMS.

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ISSUES	
DESCRIPTION	DATE (yy/mm/da)
FOR PRELIMINARY	–
FOR APPROVAL	–
FOR TENDER	–
FOR CONSTRUCTION	–
FOR RECORD	–
FOR ARCHIVE	–

LEGEND

EXISTING

- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
- DRAINAGE FLOW
- LAMP STANDARD
- HYDRO POLE
- MAJOR DRAINAGE FLOW
- 684.0 PREDEVELOPMENT CONTOURS

PROPOSED

- EDGE OF GRAVEL
- TOP OF LOW PERMEABILITY MATERIAL
- TOP/TOE OF SLOPE
- DITCH
- 200 YEAR FLOOD ELEVATION 638.20
- 100 YEAR FLOOD ELEVATION 637.85
- 50 YEAR FLOOD ELEVATION 637.55
- 20 YEAR FLOOD ELEVATION 637.20
- 10 YEAR FLOOD ELEVATION 636.90

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REVISIONS

DES.	PL
DWN.	RR
DATE	11–02–25
CHK.	CG

P. ENG. – DATE YY–MM–DD

SCALE H 1:500
V 1:50

URBANSYSTEMS.
VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

SOUTH ALIGNMENT OPTION 1 PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 5 OF 14

DRAWING No. C04–0613.0046.01

DESTROY ALL PRINTS PRIOR TO

R 0

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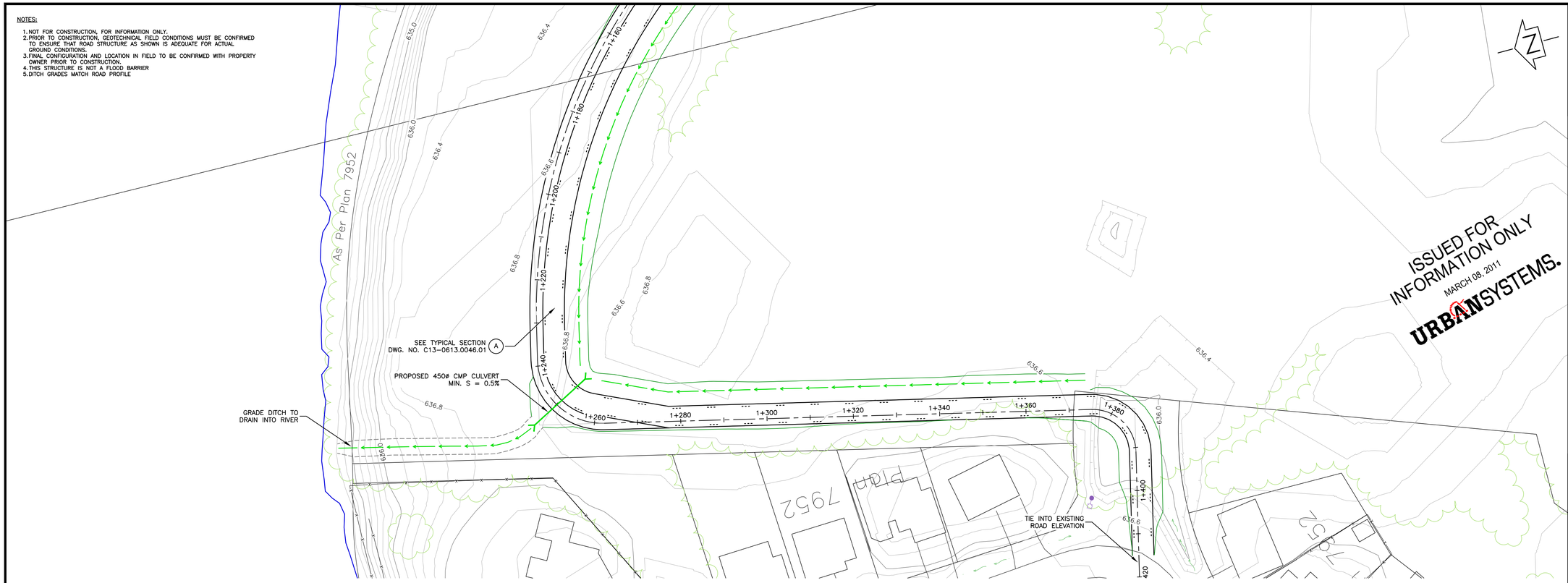
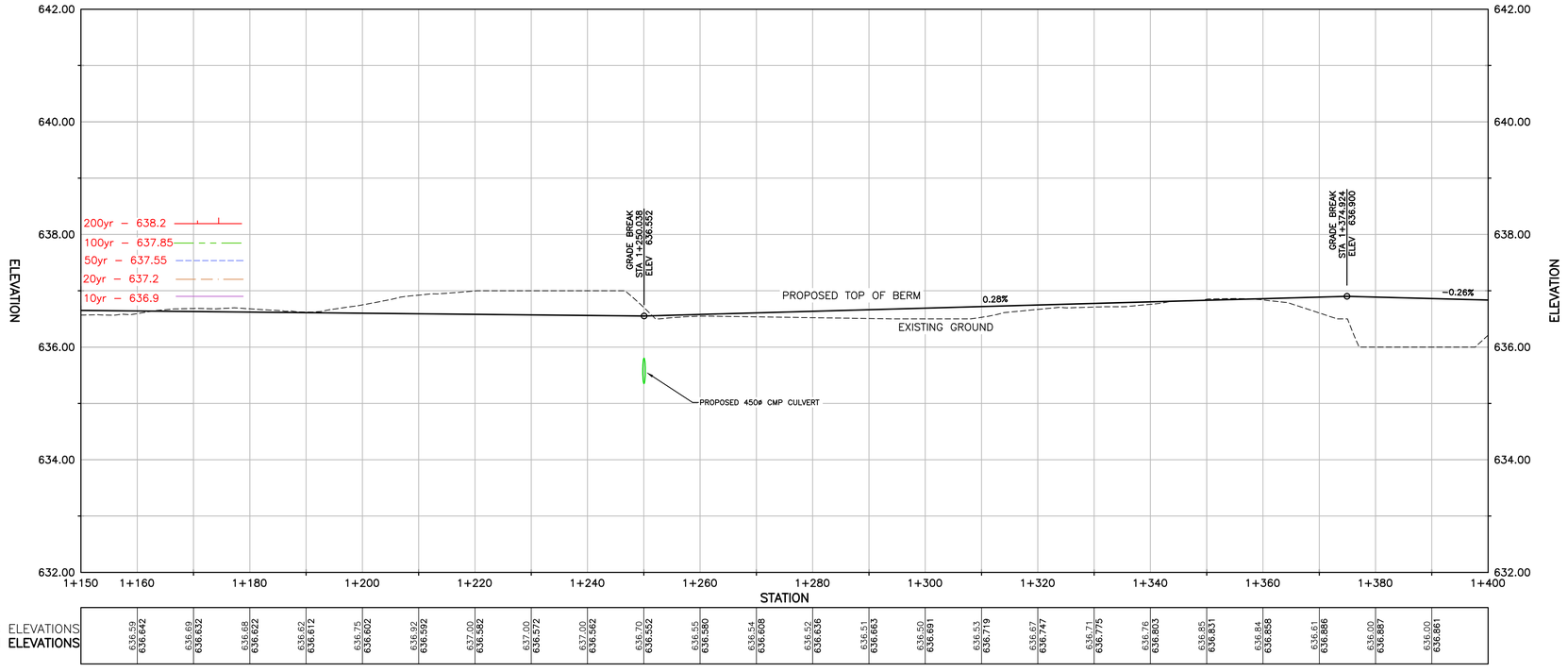
5. DITCH GRADES MATCH ROAD PROFILE





EXISTING ELEVATIONS / BERM ELEVATIONS																									
	636.59 / 636.842	636.69 / 636.632	636.68 / 636.622	636.62 / 636.612	636.75 / 636.602	636.92 / 636.592	637.00 / 636.582	637.00 / 636.572	637.00 / 636.562	636.70 / 636.552	636.55 / 636.580	636.54 / 636.608	636.52 / 636.636	636.51 / 636.663	636.50 / 636.691	636.53 / 636.719	636.67 / 636.747	636.71 / 636.775	636.76 / 636.803	636.95 / 636.831	636.84 / 636.858	636.61 / 636.886	636.00 / 636.867	636.00 / 636.861

ISSUED FOR INFORMATION ONLY
MARCH 08, 2011
URBANSYSTEMS.

ISSUES	
DESCRIPTION	DATE (yy/mm/da)
FOR PRELIMINARY	–
FOR APPROVAL	–
FOR TENDER	–
FOR CONSTRUCTION	–
FOR RECORD	–
FOR ARCHIVE	–

LEGEND

EXISTING
- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
- DRAINAGE FLOW
- LAMP STANDARD
- HYDRO POLE
- PREDEVELOPMENT CONTOURS (684.0)
- MAJOR DRAINAGE FLOW

PROPOSED
- EDGE OF GRAVEL
- TOP OF LOW PERMEABILITY MATERIAL
- TOP/TOE OF SLOPE
- DITCH
- 200 YEAR FLOOD ELEVATION 638.20
- 100 YEAR FLOOD ELEVATION 637.85
- 50 YEAR FLOOD ELEVATION 637.55
- 20 YEAR FLOOD ELEVATION 637.20
- 10 YEAR FLOOD ELEVATION 636.90

NO.	yy/mm/dy	DESCRIPTION	BY	APP'D
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REVISIONS

DES.	PL
DWN.	RR
DATE	11-02-25
CHK.	CG

P. ENG. – DATE YY-MM-DD

SCALE H 1:500
V 1:50

URBANSYSTEMS.
VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

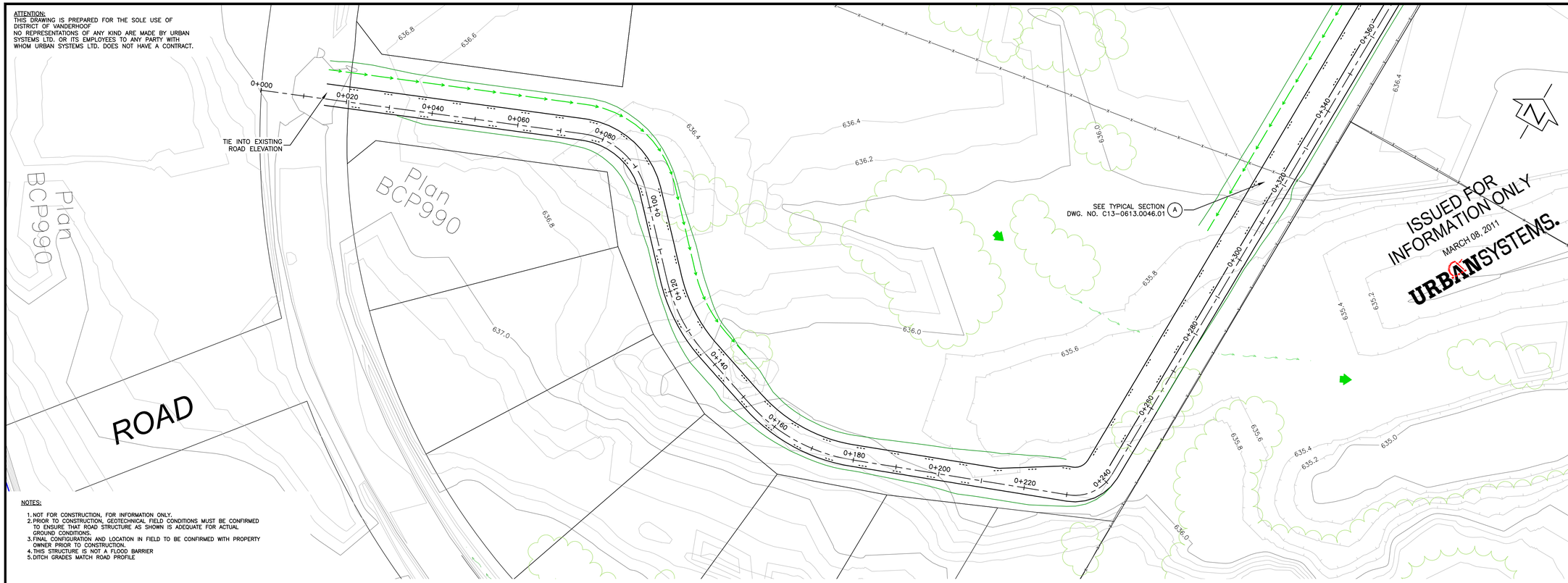
SOUTH ALIGNMENT OPTION 1 PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 6 OF 14

DRAWING No. C05-0613.0046.01

DESTROY ALL PRINTS PRIOR TO R 0



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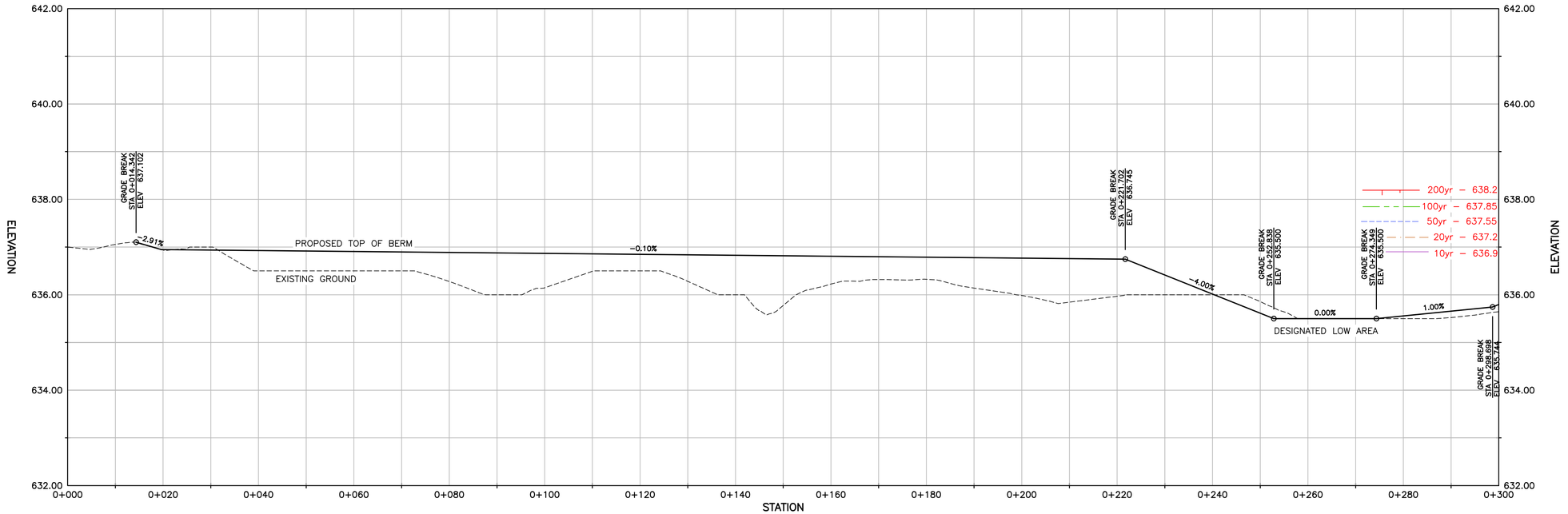
5. DITCH GRADES MATCH ROAD PROFILE



EXISTING ELEVATIONS	637.05
BERM ELEVATIONS	636.94 636.947 / 637.00 636.937 / 636.50 636.927 / 636.50 636.917 / 636.50 636.907 / 636.50 636.897 / 636.28 636.887 / 636.00 636.877 / 636.15 636.867 / 636.49 636.857 / 636.50 636.847 / 636.28 636.837 / 636.00 636.827 / 635.78 636.817 / 636.22 636.807 / 636.32 636.797 / 636.32 636.787 / 636.14 636.777 / 635.98 636.767 / 635.84 636.757 / 635.97 636.747 / 636.00 636.414 / 636.00 636.014 / 635.86 635.614 / 635.50 635.500 / 635.50 635.500 / 635.50 635.557 / 635.52 635.657

ISSUES

DESCRIPTION	DATE (yy/mm/dd)
FOR PRELIMINARY	–
FOR APPROVAL	–
FOR TENDER	–
FOR CONSTRUCTION	–
FOR RECORD	–
FOR ARCHIVE	–

LEGEND

EXISTING

- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
- DRAINAGE FLOW
- LAMP STANDARD
- HYDRO POLE
- 684.0 PREDEVELOPMENT CONTOURS
- MAJOR DRAINAGE FLOW

PROPOSED

- EDGE OF GRAVEL
- TOP OF LOW PERMEABILITY MATERIAL
- TOP/TOE OF SLOPE
- DITCH
- 200 YEAR FLOOD ELEVATION 638.20
- 100 YEAR FLOOD ELEVATION 637.85
- 50 YEAR FLOOD ELEVATION 637.55
- 20 YEAR FLOOD ELEVATION 637.20
- 10 YEAR FLOOD ELEVATION 636.90

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REVISIONS

DES.	PL
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DATE	11-02-25
CHK.	CG

P. ENG. – DATE YY-MM-DD

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V 1:50

URBANSYSTEMS.

VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

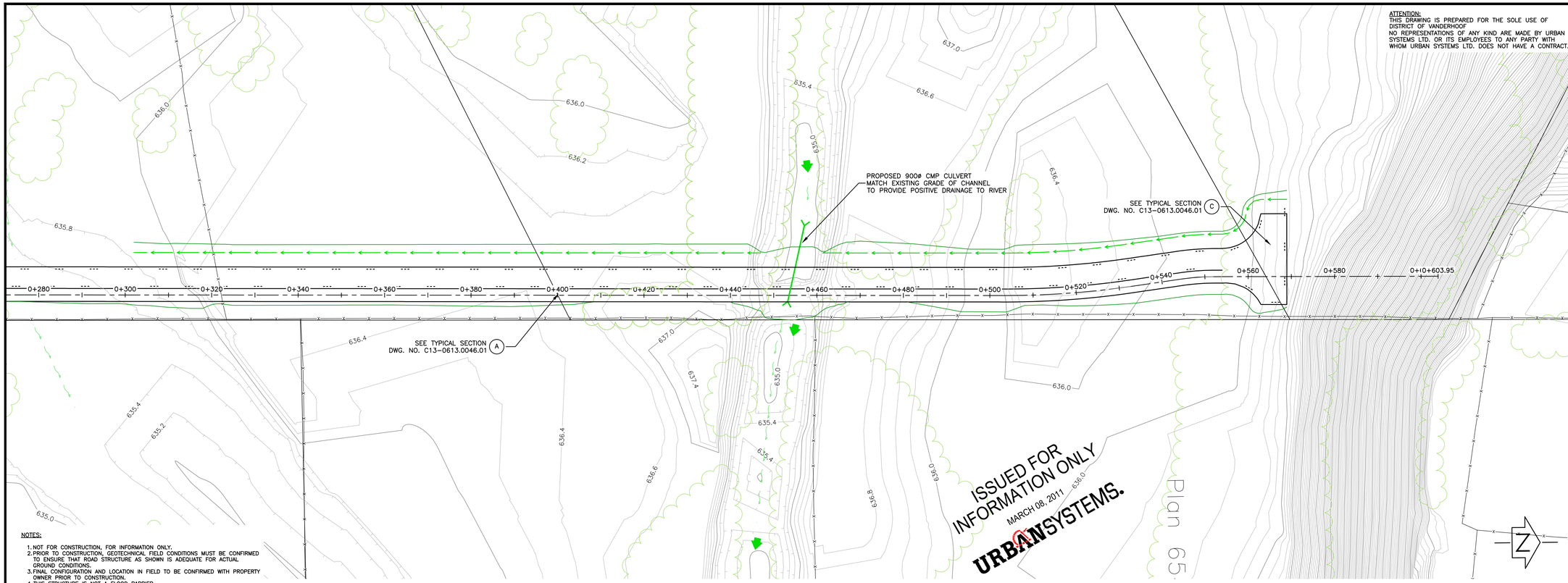
NORTH ALIGNMENT OPTION 1 PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 7 OF 14

DRAWING No. C06-0613.0046.01

DESTROY ALL PRINTS PRIOR TO R 0



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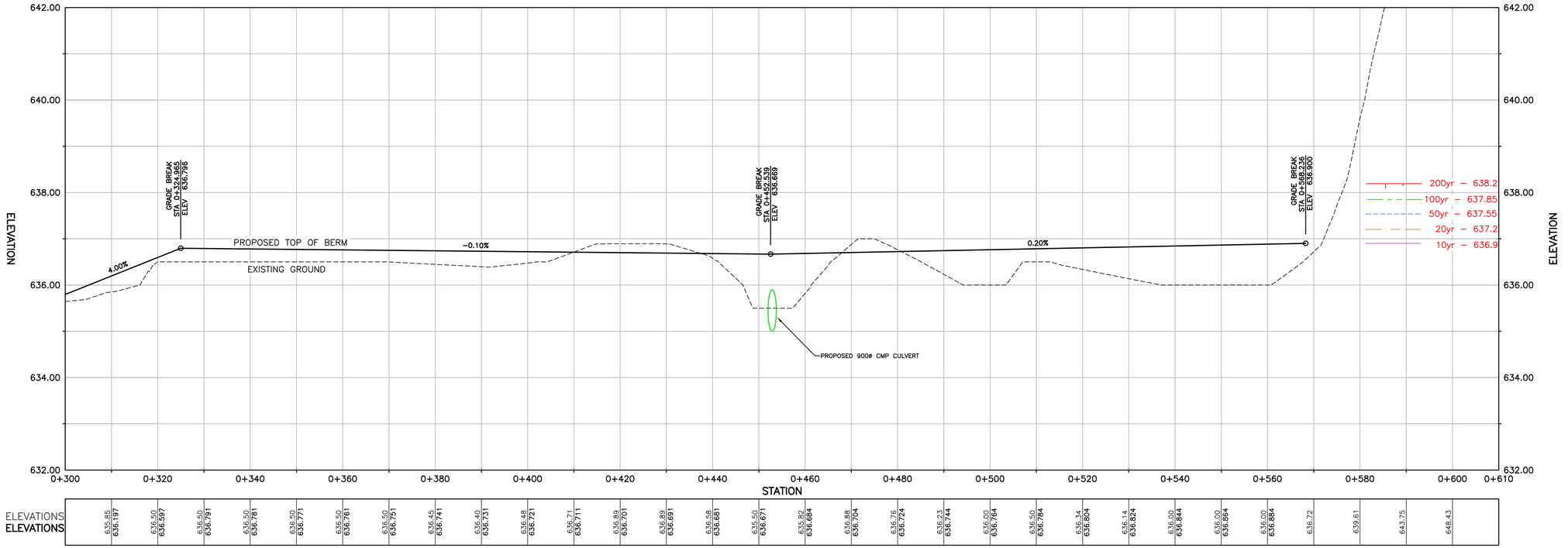

EXISTING ELEVATIONS	635.85	636.50	636.50	636.50
BERM ELEVATIONS	636.197	636.597	636.791	636.781

EXISTING ELEVATIONS	636.50	636.50	636.50	636.45
BERM ELEVATIONS	636.771	636.761	636.751	636.741

EXISTING ELEVATIONS	636.40	636.48	636.71	636.89
BERM ELEVATIONS	636.731	636.721	636.711	636.701

EXISTING ELEVATIONS	636.89	636.68	635.50	635.82
BERM ELEVATIONS	636.691	636.681	636.671	636.684

EXISTING ELEVATIONS	636.88	636.76	636.23	636.00
BERM ELEVATIONS	636.704	636.724	636.744	636.764

EXISTING ELEVATIONS	636.50	636.34	636.14	636.00
BERM ELEVATIONS	636.784	636.804	636.824	636.844

EXISTING ELEVATIONS	636.00	636.00	636.72	639.61
BERM ELEVATIONS	636.864	636.884		

EXISTING ELEVATIONS	643.75
BERM ELEVATIONS	648.43

ISSUES

DESCRIPTION	DATE (yy/mm/da)
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FOR APPROVAL	–
FOR TENDER	–
FOR CONSTRUCTION	–
FOR RECORD	–
FOR ARCHIVE	–

LEGEND

EXISTING
- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
- DRAINAGE FLOW
- LAMP STANDARD
- HYDRO POLE
- 684.0 PREDEVELOPMENT CONTOURS
- MAJOR DRAINAGE FLOW

PROPOSED
- EDGE OF GRAVEL
- TOP OF LOW PERMEABILITY MATERIAL
- TOP/TOE OF SLOPE
- DITCH
- 200 YEAR FLOOD ELEVATION 638.20
- 100 YEAR FLOOD ELEVATION 637.85
- 50 YEAR FLOOD ELEVATION 637.55
- 20 YEAR FLOOD ELEVATION 637.20
- 10 YEAR FLOOD ELEVATION 636.90

NO.	yy/mm day	DESCRIPTION	BY	APP'D
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REVISIONS

DES. PL
DWN. RR
DATE 11-02-25
CHK. CG

P. ENG. – DATE YY-MM-DD

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URBANSYSTEMS.
VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

NORTH ALIGNMENT OPTION 1 PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 8 OF 14

DRAWING No. C07-0613.0046.01

DESTROY ALL PRINTS PRIOR TO R 0

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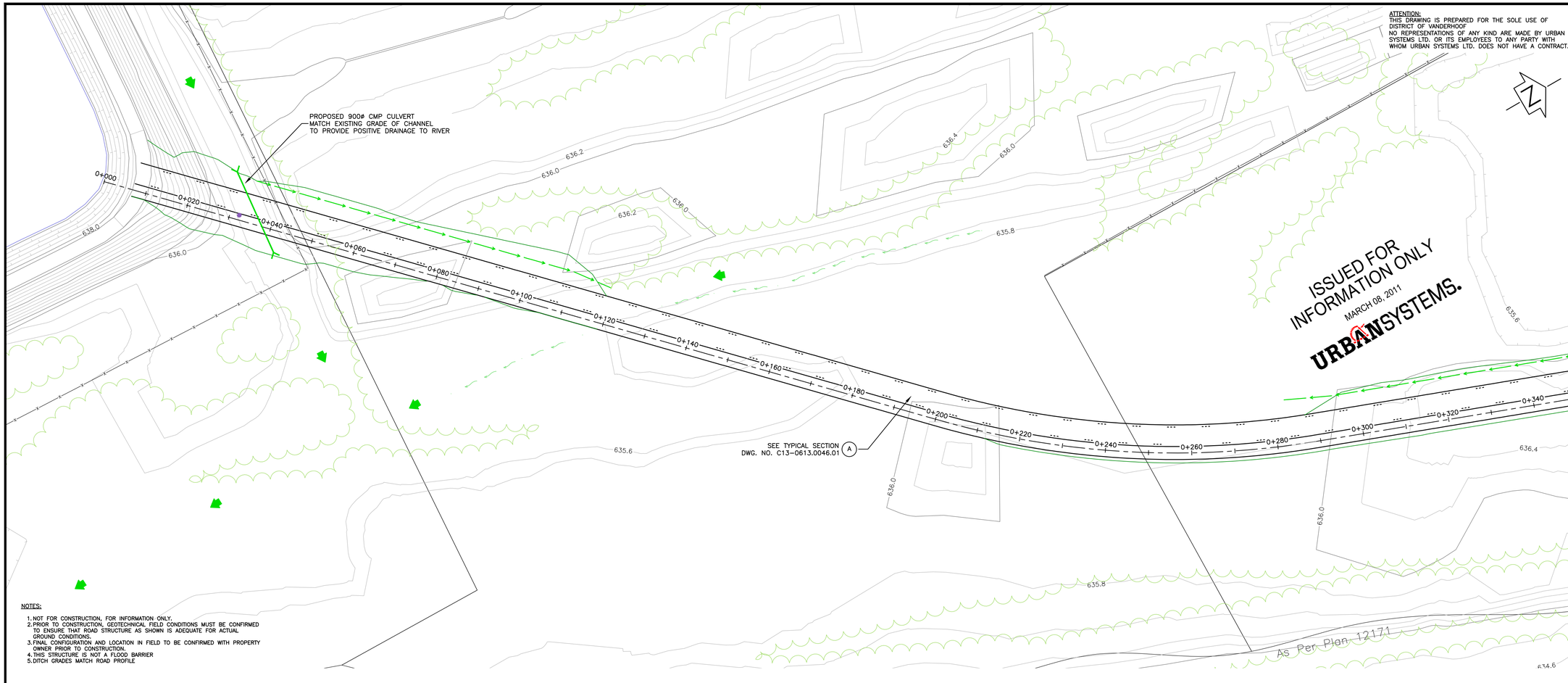

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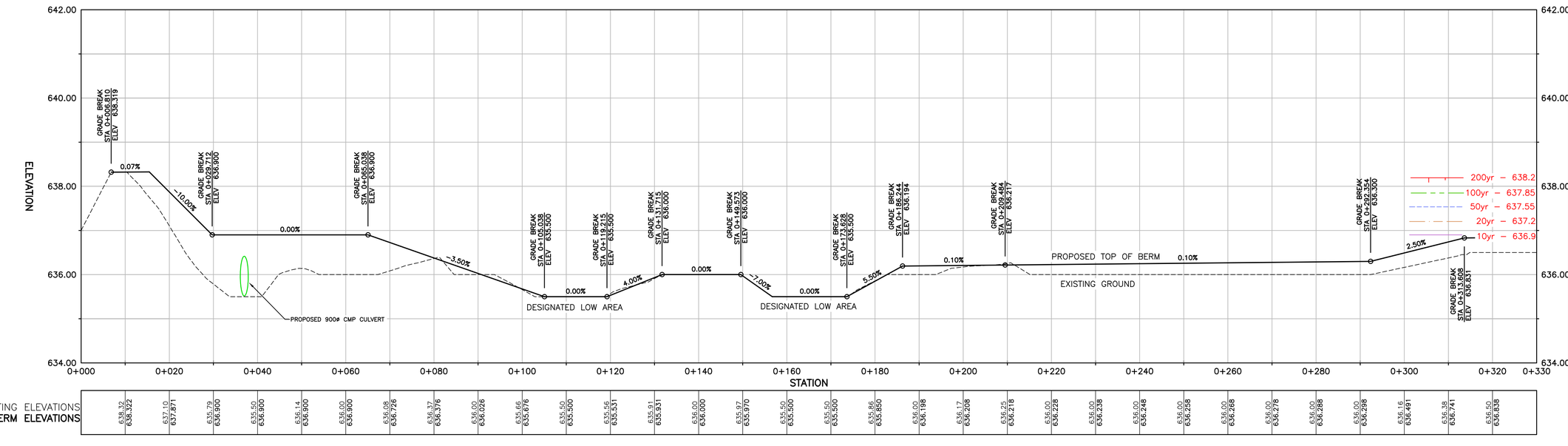

EXISTING ELEVATIONS	638.32	637.10	635.79	635.50	636.14	636.00	636.08	636.37	636.00	635.66	635.50	635.56	635.91	636.00	635.97	635.50	635.50	635.86	636.00	636.17	636.25	636.00	636.00	636.00	636.00	636.00	636.00	636.00	636.16	636.38	636.50
BERM ELEVATIONS	638.322	637.871	636.900	636.900	636.900	636.900	636.726	636.376	636.026	635.676	635.500	635.531	635.931	636.000	635.970	635.500	635.500	635.850	636.198	636.208	636.218	636.228	636.238	636.248	636.258	636.268	636.278	636.288	636.298	636.491	636.741	636.838

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REVISIONS

ISSUES	
DESCRIPTION	DATE (yy/mm/dd)
FOR PRELIMINARY	–
FOR APPROVAL	–
FOR TENDER	–
FOR CONSTRUCTION	–
FOR RECORD	–
FOR ARCHIVE	–

LEGEND

EXISTING
- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
- DRAINAGE FLOW
- LAMP STANDARD
- HYDRO POLE
- 684.0 PREDEVELOPMENT CONTOURS
- MAJOR DRAINAGE FLOW

PROPOSED
- EDGE OF GRAVEL
- TOP OF LOW PERMEABILITY MATERIAL
- TOP/TOE OF SLOPE
- DITCH
- 200 YEAR FLOOD ELEVATION 638.20
- 100 YEAR FLOOD ELEVATION 637.85
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- 20 YEAR FLOOD ELEVATION 637.20
- 10 YEAR FLOOD ELEVATION 636.90

DES.	PL
DWN.	RR
DATE	11-02-25
CHK.	CG

P. ENG. – DATE YY-MM-DD

SCALE H 1:500
V 1:50

URBANSYSTEMS.

VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

SOUTH ALIGNMENT OPTION 2 PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 9 OF 14

DRAWING No. C08-0613.0046.01

DESTROY ALL PRINTS PRIOR TO R 0

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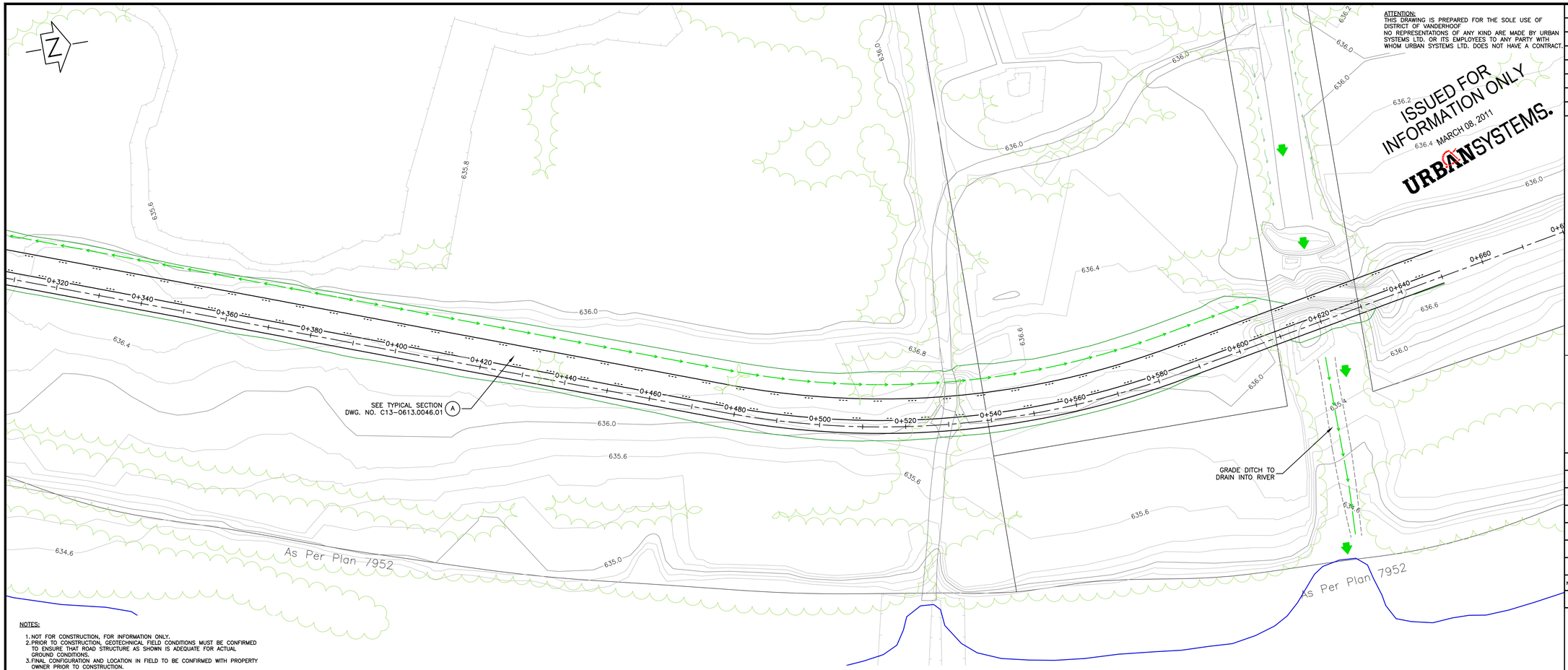

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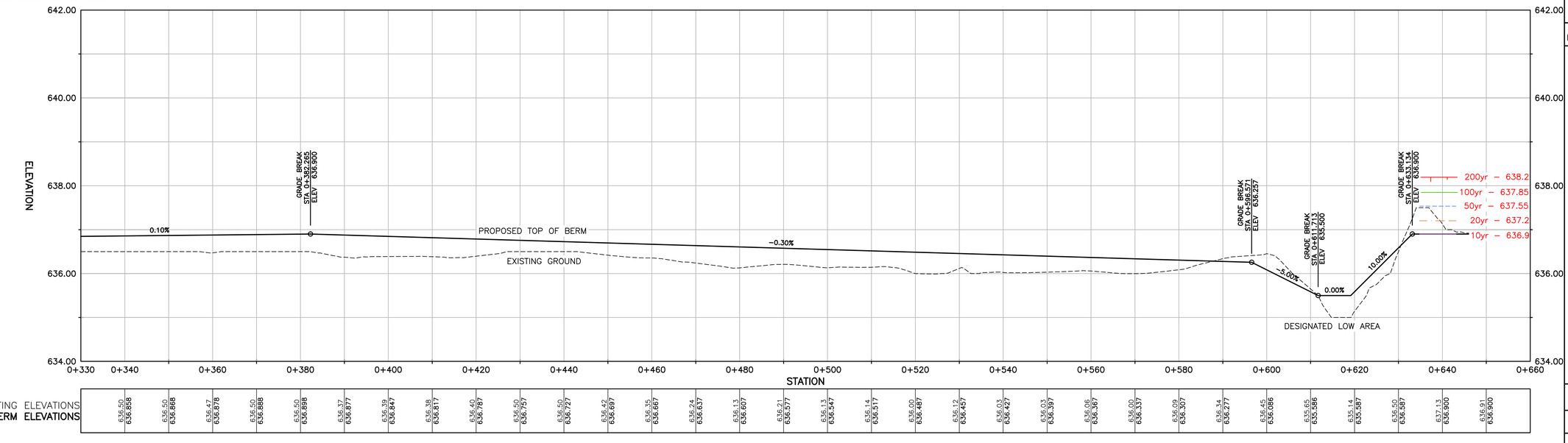

ISSUES

DESCRIPTION	DATE (yy/mm/da)
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FOR APPROVAL	–
FOR TENDER	–
FOR CONSTRUCTION	–
FOR RECORD	–
FOR ARCHIVE	–

LEGEND

EXISTING

- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
- DRAINAGE FLOW
- LAMP STANDARD
- HYDRO POLE
- 684.0 PREDEVELOPMENT CONTOURS
- MAJOR DRAINAGE FLOW

PROPOSED

- EDGE OF GRAVEL
- TOP OF LOW PERMEABILITY MATERIAL
- TOP/TOE OF SLOPE
- DITCH
- 200 YEAR FLOOD ELEVATION 638.20
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REVISIONS

DES. PL
DWN. RR
DATE 11-02-25
CHK. CG

P. ENG. – DATE YY-MM-DD

SCALE H 1:500
V 1:50

URBANSYSTEMS.

VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

SOUTH ALIGNMENT OPTION 2 PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 10 OF 14

DRAWING No. C09-0613.0046.01

DESTROY ALL PRINTS PRIOR TO R 0

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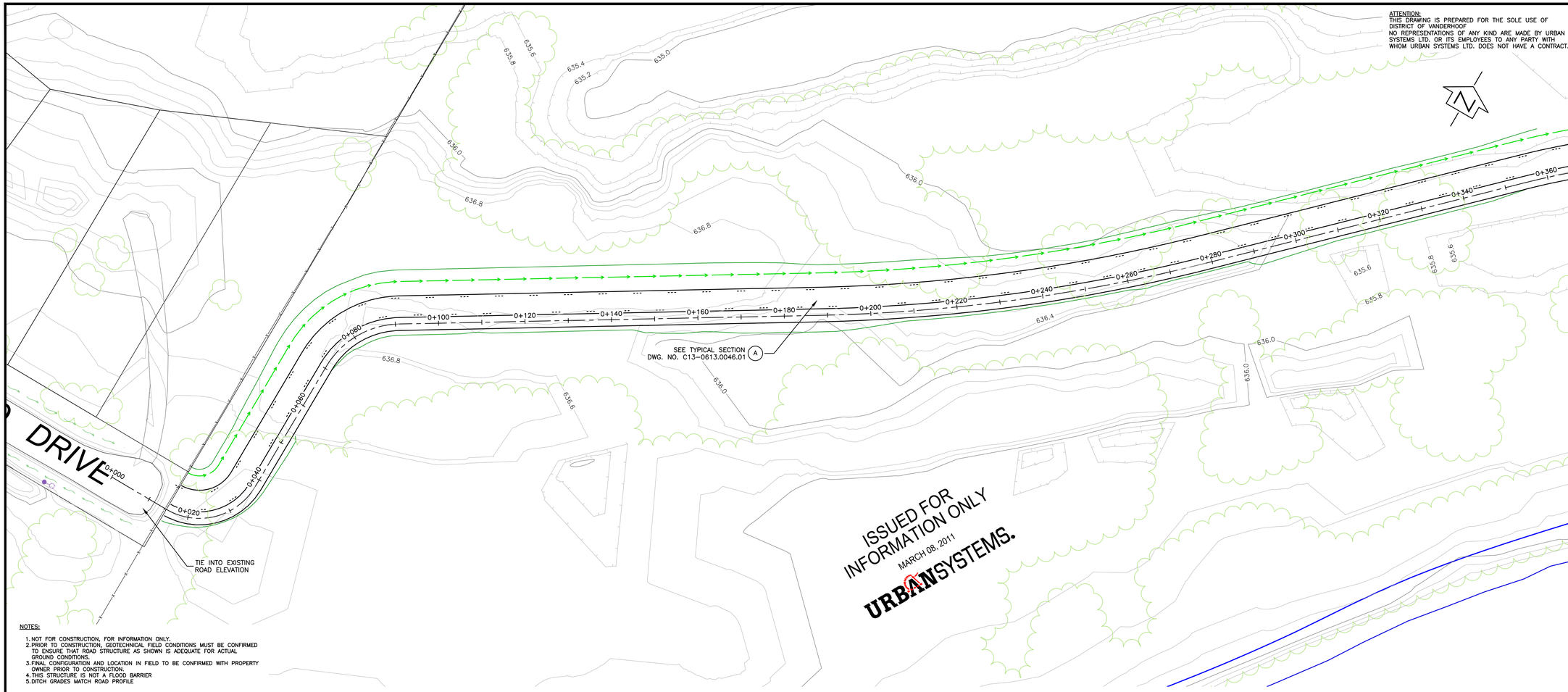

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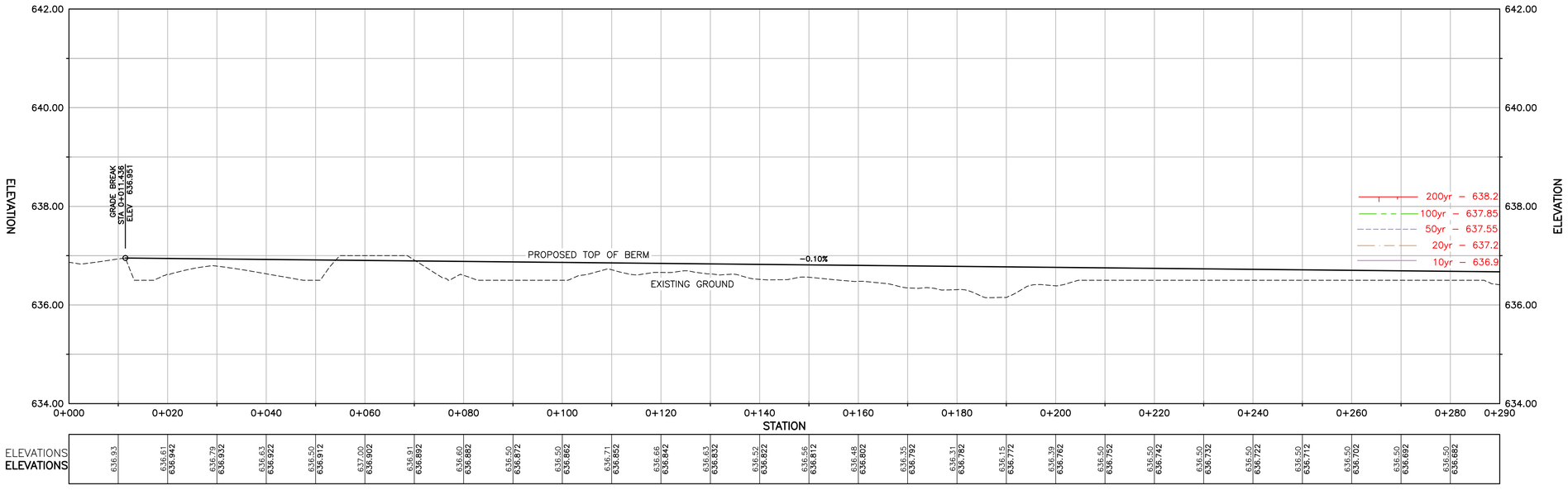

EXISTING ELEVATIONS BERM ELEVATIONS																														
	636.93	636.61 / 636.942	636.79 / 636.932	636.63 / 636.922	636.50 / 636.912	637.00 / 636.902	636.91 / 636.892	636.60 / 636.882	636.50 / 636.872	636.50 / 636.862	636.71 / 636.852	636.66 / 636.842	636.63 / 636.832	636.52 / 636.822	636.56 / 636.812	636.48 / 636.802	636.35 / 636.792	636.31 / 636.782	636.15 / 636.772	636.39 / 636.762	636.50 / 636.752	636.50 / 636.742	636.50 / 636.732	636.50 / 636.722	636.50 / 636.712	636.50 / 636.702	636.50 / 636.692	636.50 / 636.682		

ISSUES

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FOR RECORD	–
FOR ARCHIVE	–

LEGEND

EXISTING

- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
- DRAINAGE FLOW
- LAMP STANDARD
- HYDRO POLE
- 684.0 PREDEVELOPMENT CONTOURS
- MAJOR DRAINAGE FLOW

PROPOSED

- EDGE OF GRAVEL
- TOP OF LOW PERMEABILITY MATERIAL
- TOP/TOE OF SLOPE
- DITCH
- 200 YEAR FLOOD ELEVATION 638.20
- 100 YEAR FLOOD ELEVATION 637.85
- 50 YEAR FLOOD ELEVATION 637.55
- 20 YEAR FLOOD ELEVATION 637.20
- 10 YEAR FLOOD ELEVATION 636.90

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URBANSYSTEMS.

VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

NORTH ALIGNMENT OPTION 2 PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 11 OF 14

DRAWING No. C10-0613.0046.01

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SEE TYPICAL SECTION DWG. NO. C13-0613.0046.01 (A)

SEE TYPICAL SECTION DWG. NO. C13-0613.0046.01 (C)

NOTES:

1. NOT FOR CONSTRUCTION, FOR INFORMATION ONLY.
2. PRIOR TO CONSTRUCTION, GEOTECHNICAL FIELD CONDITIONS MUST BE CONFIRMED TO ENSURE THAT ROAD STRUCTURE AS SHOWN IS ADEQUATE FOR ACTUAL GROUND CONDITIONS.
3. FINAL CONFIGURATION AND LOCATION IN FIELD TO BE CONFIRMED WITH PROPERTY OWNER PRIOR TO CONSTRUCTION.
4. THIS STRUCTURE IS NOT A FLOOD BARRIER
5. DITCH GRADES MATCH ROAD PROFILE

ISSUED FOR INFORMATION ONLY
MARCH 08, 2011
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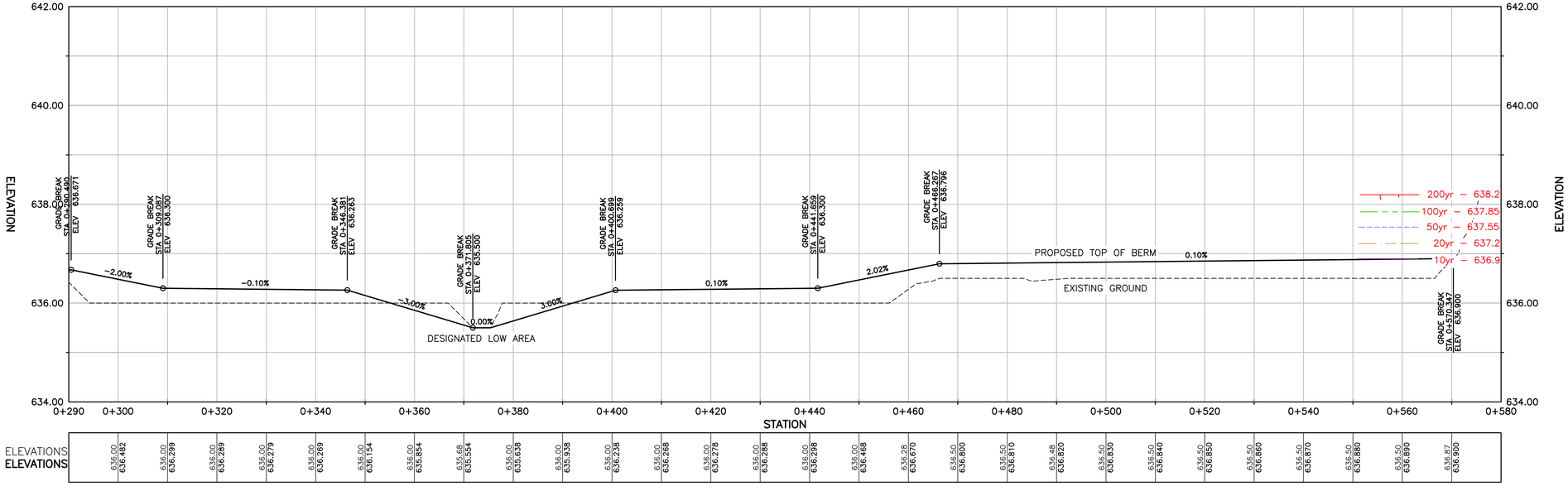

EXISTING ELEVATIONS
BERM ELEVATIONS

0+290	0+300	0+320	0+340	0+360	0+380	0+400	0+420	0+440	0+460	0+480	0+500	0+520	0+540	0+560	0+580
636.00	636.00	636.00	636.00	636.00	635.68	636.00	636.00	636.00	636.00	636.28	636.50	636.48	636.50	636.50	636.87
636.482	636.299	636.289	636.279	636.269	636.154	635.854	635.554	635.638	635.938	636.238	636.268	636.278	636.288	636.298	636.468	636.670	636.800	636.810	636.820	636.830	636.840	636.850	636.860	636.870	636.880	636.890	636.900

ISSUES

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LEGEND

EXISTING

- PROPERTY LINE
- FENCE
- BUILDING
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URBANSYSTEMS.

VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

NORTH ALIGNMENT OPTION 2 PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 12 OF 14

DRAWING No. C11-0613.0046.01

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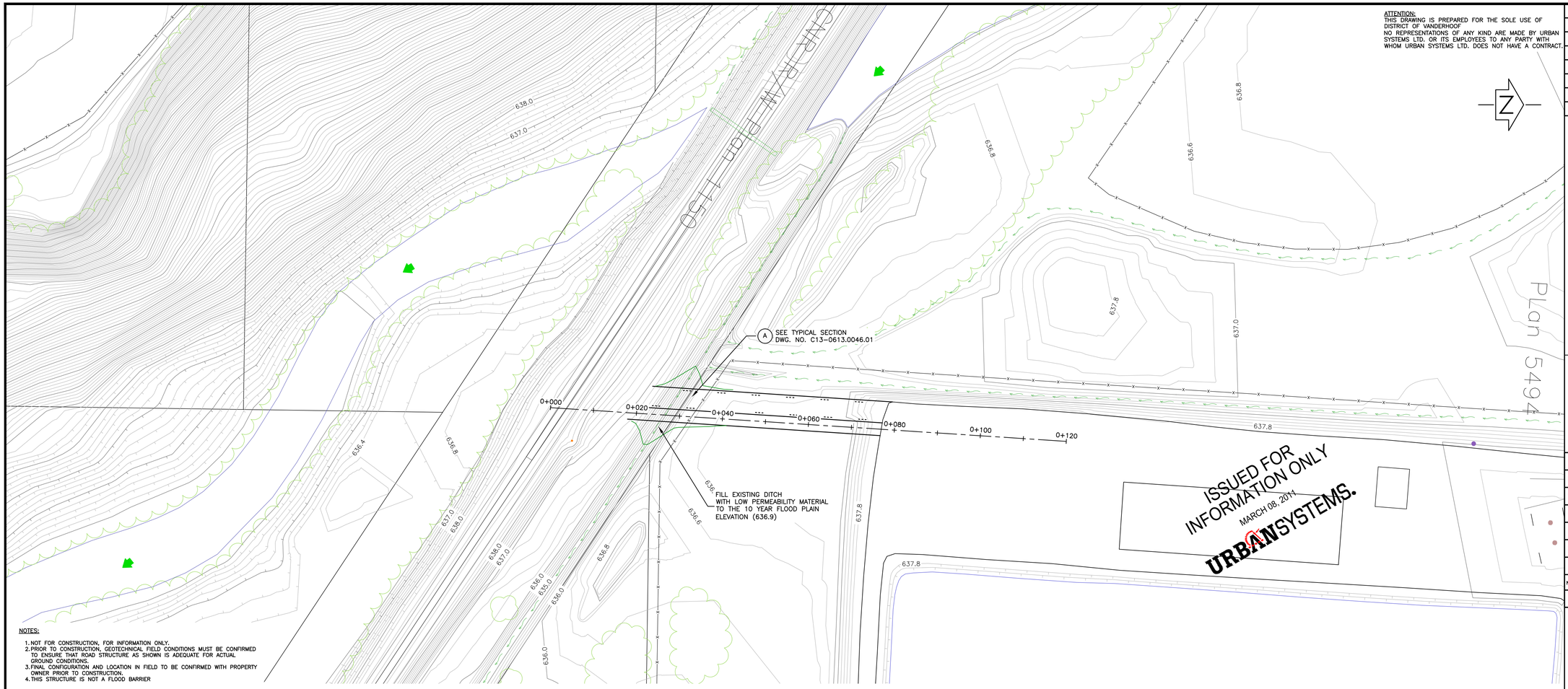

ATTENTION:
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NOTES:

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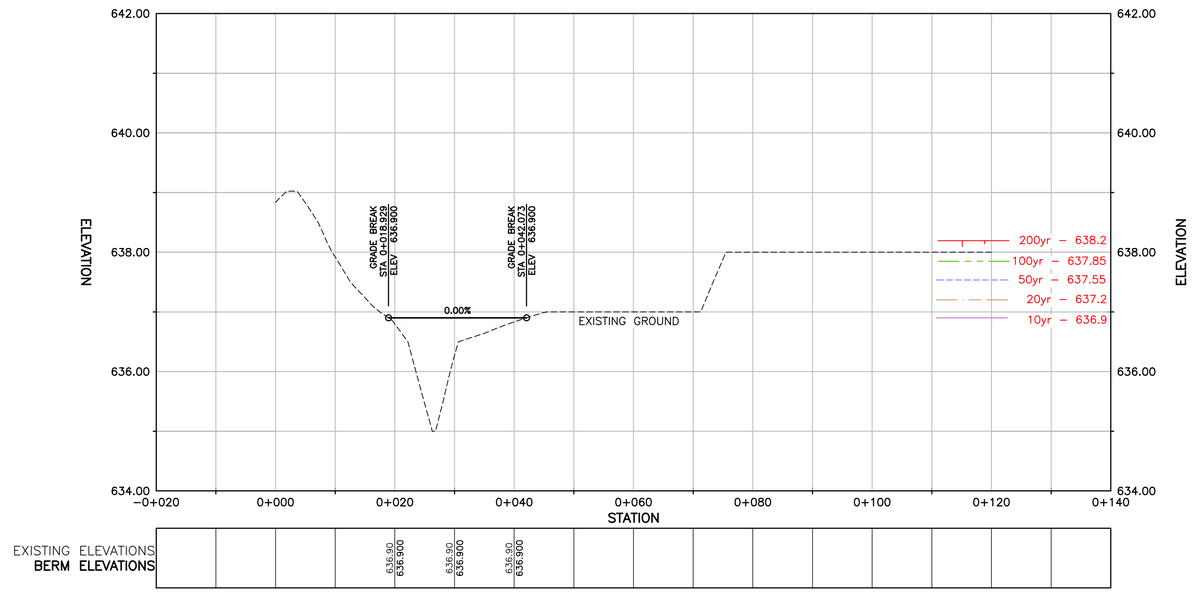
4. THIS STRUCTURE IS NOT A FLOOD BARRIER



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FOR RECORD	–
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LEGEND

EXISTING

- PROPERTY LINE
- FENCE
- BUILDING
- GRAVEL ROAD
- SANITARY MAIN
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- HYDRO POLE
- 684.0 – PREDEVELOPMENT CONTOURS
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URBANSYSTEMS.

VANDERHOOF, B.C.

FLOOD PROTECTION PLAN

SOUTH ALIGNMENT (RAILWAY) PLAN & PROFILE

PROJECT No. 0613.0046.01

SHEET 13 OF 14

DRAWING No. C12–0613.0046.01

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appendix c

District of Vanderhoof

Flood Protection Plan

Sandbag Dike Details & Quantities

VANDERHOOF FLOOD PROTECTION PLAN
Temporary Flood Protection Works - Quantities

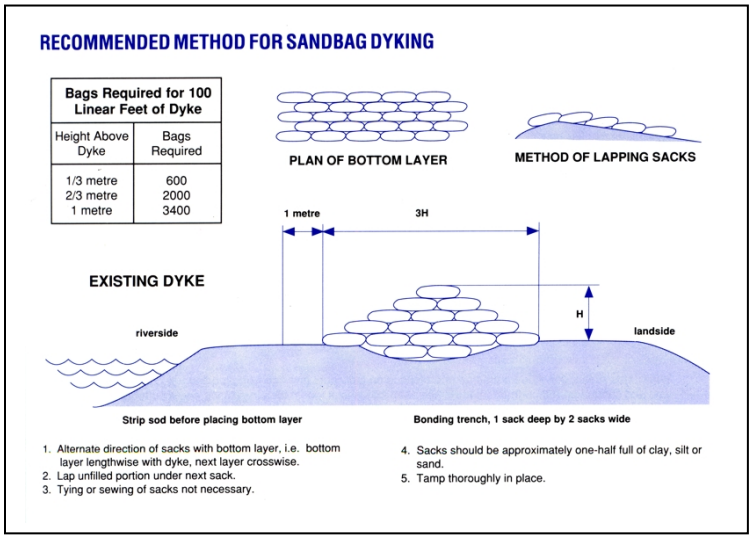
Scenario[1]	Hesco Bales	HESCO Bale Fill Material[6] (m^3)	Sand Bags[3]	Sandbag Material[3] (m^3)	Additional Fill Material[4] (m^3)	Sub-Total Material (m^3)	20% Contingency Material (m^3)	Total Material (m^3)
Sand Bag Option 1[2]								
10 Year			84000	1050	3480	4530	910	5440
20 Year			198000	2480	3480	5960	1190	7150
50 Year			363600	4550	3480	8030	1610	9640
100 Year			600300	7500	3480	10980	2200	13180
200 Year			932000	11650	3480	15130	3030	18160
Sand Bag Option 2[2]								
10 Year			84800	1060	2760	3820	760	4580
20 Year			191200	2390	2760	5150	1030	6180
50 Year			351900	4400	2760	7160	1430	8590
100 Year			596500	7460	2760	10220	2040	12260
200 Year			896900	11210	2760	13970	2790	16760
Hesco Bale Option 1[5]								
10 Year	390	2090	40000	500	0	2590	520	3110
20 Year	520	2780	83400	1040	0	3820	760	4580
50 Year	550	2940	157000	1960	0	4900	980	5880
100 Year	910	4870	273400	3420	0	8290	1660	9950
200 Year	1360	7280	407400	5090	0	12370	2470	14840
Hesco Bale Option 2[5]								
10 Year	330	1770	40000	500	0	2270	450	2720
20 Year	450	2410	83400	1040	0	3450	690	4140
50 Year	600	3210	157000	1960	0	5170	1030	6200
100 Year	810	4330	274200	3430	0	7760	1550	9310
200 Year	1200	6420	404200	5050	0	11470	2290	13760

Notes:

1. These quantities are estimates for temporary flood protection works only; permanent access road quantities are included in section 5.0 of the report.
2. Sand bag options assumes HESCO bales are not available.
3. Sand bag and sand material quantities are based on Emergency Management BC recommendations.
4. Additional fill material will be required for designated low areas during flood events, material type has been assumed to be same as for sand bags.
5. HESCO bale options include HESCO bales in undeveloped areas + open common spaces in developed areas; sand bags are proposed through back yards + some additional sand bags will be required on top of the HESCO bales to protect up to higher flood events.
6. HESCO fill material is assumed to be same as for sand bags. Fill material volumes are based on a fill of 5.35m^3 per 5 cell units (1m x 1m x 1m x 5m) as per manufacturer's recommendations.

SANDBAGGING
General Information

- Construct the sandbag dike on high ground, as close as possible to your home or building. By being closer to your home or building, fewer bags will be needed, and the sandbag dike will be less exposed to the stream.
- Sandbagging should also focus along existing flood works or any low spots along dikes for maximum protection.
- Dig a trench one bag in depth and two bags wide as a foundation for the dike structure.
- To be effective, a dike must be three times as wide at its base as it is high.
- Sandbags should be turned right side out and filled half full. They need not be tied shut, just laid overlapping each other.
- The open ends of the sandbags should be facing upstream and/or uphill so that the moving water will not remove the sand from the bags as readily.
- Alternate direction of sandbags with bottom layer, i.e. bottom layer lengthwise with dike, next layer crosswise.
- As individual bags are put in place, walk on bags to tamp them into place to ensure maximum strength. Take care to avoid puncturing the bags.
- The butt ends of the bags should be placed facing the stream, for rows that are perpendicular to the stream.
- Each successive layer should be set back one-half sandbag width on both sides in each additional layer so a completed dike has a triangular cross-section.
- The number of sandbags needed to protect a home or building varies depending on the local topography and the anticipated depth of water.



appendix d

District of Vanderhoof
Flood Protection Plan

Geotechnical Report (AMEC Earth & Environmental)

URBANSYSTEMS.

KX05261
28 February 2011

District of Vanderhoof
c/o Urban Systems Ltd.
200 – 286 St. Paul Street
Kamloops, BC V2C 6G4

Attention: Mr. Pablo Lopez, P.Eng.

RE: PRELIMINARY GEOTECHNICAL RECOMMENDATIONS FOR WORKS ASSOCIATED WITH THE VANDERHOOF FLOOD PROTECTION PLAN VANDERHOOF, BC

1.0 INTRODUCTION

AMEC Earth & Environmental, a division of AMEC Americas Limited (AMEC), is pleased to provide the following letter report as requested by Urban Systems Ltd. (USL), on behalf of the District of Vanderhoof (DoV) for the above mentioned project. AMEC understands that the DoV is preparing a flood protection plan that includes construction access road and base structures along the Nechako River to facilitate future placement of temporary flood protection measures should they be required. This letter presents the preliminary concept-level geotechnical recommendations in support of the of the works associated with the flood protection plan, as outlined in the scope provided in email correspondence between AMEC and USL on 5 January 2011. The following tasks were outlined in the scope:

- Review and summarize existing background geotechnical information;
- Provide general geotechnical recommendations for design and construction of temporary access roads and base structures for flood protection measures based on existing site information only; and,
- Provide additional geotechnical input as required during the design phase.

AMEC understands that certain restrictions apply to the design of the project as discussed between USL, DoV, and the provincial Dike Maintenance Inspector. According to conversations with USL, AMEC understands the design must meet the following requirements:

- The structures must be no more than 1.0 m in height (above original ground);
- The structures must be no higher than the 10-year return period flood elevation; and,
- The structures must be discontinuous along the alignment (i.e. cannot be constructed to contain/restrict water flow);

AMEC was retained to assess geotechnical aspects of the project as listed above. Note that our scope of work did not include hydraulic/seepage design, consideration of environmental aspects of the project, or consideration of the effectiveness of the temporary structures proposed by others. The discussions and recommendations provided within this letter are general in nature, and focus on the geotechnical stability and constructability of the proposed structures from a

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conceptual geotechnical engineering standpoint only, including comments regarding general soil permeability characteristics that may be encountered in the project area.

For clarity within this letter the following terminology will be used to describe the various components of the proposed structure:

"*Access road*" – refers to the land-side, travelled portion of the structure constructed out of free-draining, granular materials.

"*Base structure*" – refers to the riverside portion of the structure, intended as the base for placement of temporary flood control baskets constructed of low permeability materials.

"Embankment structure" – refers to the completed section comprised of both the "*access road*" and "*base structure*" components as a whole.

2.0 SITE DESCRIPTION

The project site is located along the Nechako River floodplain in Vanderhoof, BC. The project limits are bounded by Burrard Avenue to the west, the CN Railway embankment to the south, East Sackner Road to the north, and the Nechako River to the east near the terminus of Sandy Beach Road. The topography in the area is generally flat-lying to gently rolling, with less than 2 to 3 m of relief across the site. Existing commercial, municipal and residential infrastructure covers about half of the project area; however, the proposed embankment structures are to be located mainly in undeveloped areas to the east. Figure 1 shows the location of the overall site and project boundaries.

3.0 BACKGROUND INFORMATION

In preparation of the preliminary geotechnical recommendations contained within this letter, AMEC relied on the following information as completed by others:

- BC Ministry of Transportation and Highways, *"Report on Route Geotechnical Investigation for Nechako River Crossing – Vanderhoof (Burrard Ave. And Loop Road Approaches)"*, 27 June 1989. Internal report.

- GeoNorth Engineering Ltd., *"Geotechnical Report – 2003 Sewage Treatment Plant Upgrade"*, 7 April 2003. Prepared for District of Vanderhoof c/o Urban Systems Ltd.

- GeoNorth Engineering Ltd., *"Geotechnical Report – Proposed Sports Field and Stadium, Vanderhoof, BC"*, 4 February, 2008. Prepared for District of Vanderhoof c/o Urban Systems Ltd.

- GeoNorth Engineering Ltd., *"Letter Report – Upgrade to Sanitary System, Manhole 4A to Manhole 3A, South from Stewart Street and East of Burrard Avenue, Vanderhoof, BC",* 15 May 2008. Prepared for District of Vanderhoof c/o Urban Systems Ltd.

- GeoNorth Engineering Ltd., *"Geotechnical Report - Proposed Flood Control Dike Adjacent to Nechako River, Vanderhoof, BC"*, 27 May 2009. Prepared for District of Vanderhoof c/o Urban Systems Ltd.

- BGC Engineering Inc., *"Preliminary Hydrogeologic Assessment – Fourth Street Road Construction Project, Vanderhoof, BC"*, 11 January 2010. Prepared for District of Vanderhoof c/o Urban Systems Ltd.

The following brief summaries include the details used from each specific report in preparation of this letter.

BC Ministry of Transportation and Highways 1989 – Nechako River Crossing

A geotechnical investigation was completed by BC Ministry of Transportation and Highways (BC MoT) for a new bridge crossing of the Nechako River between Burrard Avenue and Loop Road. Two existing areas of instability were identified along Loop Road, on the upstream side of the proposed bridge alignment. A total of 25 drill holes were completed between 8.8 and 25 m depth, the majority of which focused on characterizing the existing berm and previously unstable area upstream of the bridge alignment on the north side of the river.

The drill holes encountered differing stratigraphies on the north and south sides of the Nechako River. The southern approach area was indicated to be underlain by between 0.6 and 1.2 m of firm, wet, sandy silt/clay and topsoil, overlying 4 to 5 m of compact to dense, sands and gravels, overlying more than 20 m of soft to firm, low plastic silty clay with interbedded sand seams. The water table was reported as being within 2.5 m of ground surface along the floodplain.

The north approach was reportedly more complex than the south side. In general, the drill holes (on the downstream side of the bridge only) indicated up to 5 m of silty and/or clayey gravel and sand, overlying firm to stiff, silty clay or glacial till. The majority of the drill holes on the north side did indicate stiff to hard clay till at depth along the north side of the Nechako; however, the depths to glacial till below surface were highly variable. The silty clay was described as wet with moisture contents approaching the average liquid limit of 33%. Undrained strength values of the silty clay were reported to be highly variable, but averaged 47 and 64 kPa for field and laboratory tests respectively. The glacial till was described as hard, sandy, medium plastic clay till with moisture contents at or below the plastic limit. The water table observed on the north side generally corresponded with the level of the Nechako River.

GeoNorth Engineering Ltd. 2003 – Sewage Treatment Plant Upgrade

A geotechnical investigation was completed by GeoNorth Engineering Ltd. (GEL) for the proposed deepening of an existing sanitary lagoon, and the construction of two concrete mixing and aeration tanks adjacent to the Nechako River in the vicinity of the eastern terminus of Stewart Street. A total of 8 drill holes (6 drill holes from a previous phase in 1999) were completed through and adjacent to the existing lagoon berms to depths between 12.6 and 21.9 m depth. The drill holes encountered approximately 0 to 2.3 m of silt, over 2.1 to 5.5 m of sand, over clayey silt. The silt was described as sandy, firm to stiff, and wet. The sand was described as loose to compact, brown, damp to saturated, with variable amounts of gravel. The clayey silt was described as layered, soft to stiff, intermediate to high plasticity, grey, and saturated with occasional sand and clay layers up to 50 mm thick. The top surface of the sand layer was

reported to slope down towards the east. The water level measurements in the sand unit indicated a water table at approximately 633.8 m elevation (approximately 4.4 m below the top of the lagoon berm), while measurements from within the deeper clayey silt unit indicated a piezometric surface up to 635.7 m (approximately 2.5 m below the top of the lagoon berm, or 1.95 m above the water level reported in the sand unit). The height of the existing berms or elevation of the ground surface alongside the lagoon berms is not reported; however, based on surrounding drill hole survey information it appears the local ground surface is at approximately 636.4 to 636.9 m in elevation.

GeoNorth Engineering Ltd. 2008 – Proposed Sports Field and Stadium

A geotechnical investigation was completed by GEL for a proposed stadium and 400 m running track located northwest of the intersection of Stewart Street and Creasy Avenue. A total of 6 test pits were excavated to between 2.3 and 3.2 m depth. The test pits encountered about 0.1 m of organic silt/grass, over 0.5 to 3.1 m clayey silt, over fine- to medium-grained sand. Clayey silt fill was also encountered in 2 test pits to a depth of between 0.5 and 1.6 m. The clayey silt was described as low to intermediate plasticity, stiff and moist with fine sand layers below 1.5 m depth. The sand was described as loose to compact, grey-brown and wet. Seepage was encountered in the test pits between 1.2 and 2.8 m depth, and the walls of the test pits were reported to slump due to the seepage and loose nature of the soil.

GeoNorth Engineering Ltd. 2008 – Upgrade to Sanitary System

A geotechnical investigation was completed by GEL for an upgrade of the sanitary system in the vicinity of Stewart Street and Burrard Avenue. A total of 2 drill holes were completed to a depth of 6.7 m. The drill holes encountered roughly 0.9 m of existing pavement structure (asphalt over sandy gravel fill), overlying sand with variable amounts of gravel to between 5.1 and 6.7 m depth. Silt with some fine-grained sand was encountered below 5.1 m in one of the drill holes. The sand was described as compact, brown to grey, and moist to wet. The silt was described as loose, non-plastic, grey and wet. Seepage was encountered at 2.1 m and 2.3 m depth in the drill holes. Groundwater levels were reported to be approximately 2.3 m below surface (635.7 m elevation). The report recommended dewatering of the area prior to excavation for the sanitary lines.

GeoNorth Engineering Ltd. 2009 – Proposed Flood Control Dike

A geotechnical investigation was completed by GEL for a proposed permanent dike approximately 680 m long adjacent to the Nechako River between Sandy Beach Road and the existing CN Rail embankment. A total of 6 drill holes and 16 Cone Penetration Test (CPT) soundings were completed along the proposed alignment. The drill holes were completed to between 4.6 and 6.1 m depth, while the CPT soundings were completed to between 4 and 11.7 m depth.

In general, the stratigraphy was represented as 4 main units consisting of approximately 0.2 to 0.4 m of silt (Unit 1), over silt and fine-grained sand to between 3 and 4 m depth (Unit 2), over gravelly sand to between 5 and 7 m depth (Unit 3), over clayey silt to silty sand (Unit 4). Bedrock was not encountered in any of the drill holes or soundings. The summarized unit descriptions are provided below:

- Unit 1: The upper silt unit was described as containing trace fine-grained sand, layered, stiff, intermediate plasticity, brown and moist. The upper silt unit was interpreted as an overbank deposit.
- Unit 2: The silt and fine-grained sand unit was described as layered, compact, non-plastic, rust coloured to light brown and moist with trace clay. The silt and fine-grained sand unit was reported to become slightly coarser with depth becoming primarily fine-grained sand with some fines. The silt and fine-grained sand unit was interpreted as a fluvial deposit.
- Unit 3: The gravelly sand unit was described as containing very little fines (trace fines to clean), brown, and wet. The gravelly sand unit was interpreted as a fluvial or glaciofluvial deposit. Towards the south end of the project area, this unit was reported to contain occasional layers from units 2 and 4.
- Unit 4: The clayey silt to silty sand unit was described as layered, very stiff, low to intermediate plasticity, grey, and wet. The clayey silt to silty sand unit was interpreted as a glaciolacustrine deposit.

The typical groundwater level was reported to be at 2.5 m depth, generally corresponding to the water levels in the Nechako River.

Additional information reported by GEL based on observations by DoV staff (Mr. Paul Hascarl, Public Works Superintendent) during the 2007 flood event indicated the following:

- Up to 1.5 m of flood water was retained by temporary sandbag dikes, while as much as 0.5 m of water was allowed to accumulate on the land side of the dikes.
- The development of sand boils behind the dikes (indicative of high seepage pressures) was not observed during the flood event.

BGC Engineering Inc. 2010 – Fourth Street Road Construction

A preliminary hydrogeological assessment was completed by BGC Engineering Inc. (BGC) for a proposed upgrade to road surface, utility and drainage systems along an 800 m section of Fourth Street. The assessment included an information review, aerial photograph interpretation and terrain assessment, as well as a site visit. The majority of the assessment was focused outside the current AMEC project area or at an overview level only and therefore does not provide much in the way of additional information from that contained within the previously summarized reports.

4.0 SUBSURFACE CONDITIONS

The majority of the project area is composed of flat-lying floodplain topography, with a generally thin but possibly locally thicker layer of topsoil and/or organic soils (peat) at surface, underlain by fluvial, glaciofluvial, glaciolacustrine deposits of silt, sand and some variable clay and gravel content, and clay rich glacial moraine or till deposits. In general, the upper units tend to dip slightly towards the river (i.e. the elevation of the unit contacts drops in elevation towards the river). Further description of the specific soil units is provided below.

4.1 SOIL CONDITIONS

The following unit descriptions are based on the summarized report information as outlined above.

1. **ORGANICS:** A layer of organics, typically composed of topsoil or peat, was encountered at surface extending to about 0.1 m in some of the drill holes and CPT sounding locations. Organic soils are typically soft, highly compressible, high in moisture content, and are considered unsuitable for construction and bearing as fill foundations. Locally deeper pockets of organic material up to at least 0.5 m may be encountered in the project area.

2. **SILT:** A layer of silt between 0.2 and 0.4 m thick was encountered at surface on the south side of the Nechako River. The silt was observed to be stiff, intermediate plastic, brown, moist and was interpreted as a fluvial deposit. These fluvial sediments are generally imperfectly to moderately drained, compressible, and subject to swelling/shrinking upon changes in moisture content and significant frost heave/settlement due to ice lens formation. This material tends to be highly sensitive when disturbed in a wet condition.

3. **SILTY SAND:** A layer of silty sand with trace clay grading to fine sand with some fines at depth, was encountered in most of the drill holes and CPT sounding locations. The silty sand was observed to between 1 and 4 m thick. The silty sand was generally loose to compact, non-plastic, light brown, moist to wet, and was interpreted as a fluvial or glaciofluvial deposit. This material can be sensitive to disturbance and difficult to work with when in a wet condition.

4. **SAND AND GRAVEL:** Sand and Gravel was encountered below the silty sand layer in most of the drill hole and CPT sounding locations. The sand and gravel contained relatively few fines (less than 10% by weight of silt and clay particles finer than 0.075mm) and was observed to be on the order of 1 to 4 m in thickness. The sand and gravel was interpreted as a glaciofluvial deposit. Glaciofluvial deposits are typically composed of poorly graded sand and gravel, with very little fines content. Glaciofluvial deposits are generally quite permeable, are well drained when above the water table, have low to moderate compressibility, can be loose to dense, and relatively high in shear strength with low susceptibility to shrinking/swelling upon changes in moisture content. Due to the nature of the deposition in the study area, the occurrence of sand and gravel can be expected to be highly variable and discontinuous both laterally and vertically.

5. **CLAYEY SILT:** A layer of clayey silt to silty sand was encountered below the sand and gravel unit to depths greater than 20 m in some locations. The clayey silt was described as layered, variable in strength (soft to stiff), low to high plastic, brown to grey, moist to wet, and was interpreted as a glaciolacustrine deposit. Glaciolacustrine deposits are typically composed of clay, silt and sand with variable but minor amounts of gravel. Glaciolacustrine soils are typically found to be on the order of several metres thick in the region, and are generally poorly drained, compressible, variable in shear strength (though usually low), and subject to swelling/shrinking upon changes in moisture content and significant frost heave/settlement due to ice lens formation. The material is also quite sensitive to disturbance and can be difficult to work with when wet.

6. **GLACIAL TILL:** Till was encountered on the north side of the Nechako River near the present Burrard Avenue bridge location (downstream side). The till was described as sandy clay, stiff to hard, grey and moist, and was encountered at variable depths in variable thicknesses, although it was typically encountered below 5 m depth. Till is also present underlying the valley slope south of the CN Railway embankment. Glacial moraine or till deposits in the region vary in composition from fine-grained (clay, silt) to coarse-grained (cobble, boulder) soil in all possible combinations. Moraine/till deposits are typically found to be poorly drained with low compressibility, relatively high shear strength, and low susceptibility to shrinking/swelling upon changes in moisture content.

4.2 GROUNDWATER CONDITIONS

According to the existing information, groundwater levels across the project site typically average about 2.5 m depth below ground surface depending on seasonal variability. This is generally expected to correspond with and be controlled by the level of the Nechako River. At certain locations an upward gradient (increasing total head pressures with depth) and/or artesian conditions have been documented within and below the fine-grained soils at depth.

5.0 DISCUSSION

Based on the information contained within the background reports, the proposed design concept and alignment and the project requirements, the following important points are highlighted:

- It is assumed that the access road must be designed to perform during emergency situations under heavy-duty construction traffic loading in extreme conditions (i.e. spring thaw/fully saturated high groundwater conditions). In order to perform as intended, the access road will require a significant structural thickness, adequate drainage, and high quality construction methods and materials.
- Frost-susceptible sensitive fine grained soils (primarily silts, some clays) were encountered at surface in several of the drill holes and will likely be encountered under the majority of the planned project area. Design of the access road structures and drainage ditches should account for such potentially weak frost-susceptible subgrade conditions.
- It is assumed that the base structure (river side of the access road) will be constructed using locally obtained, low permeability materials such as silt, clay, or clay till, preferably from an on-site source. It is further assumed that this material will be selected and compacted such that it will be able to carry the weight of temporary dyking that would be added at a later date. The advantages and disadvantages of each potential borrow material, their associated handling characteristics, and the potential risks to construction schedule and cost should be considered when determining material suitability for the project. The silt, clay and clay till materials will likely all perform well if they can be borrowed/handled/placed in relatively dry conditions at moisture contents conducive to good compaction; however, should the borrow materials be wet when excavated, or become wet during construction, they will be difficult to work with and may require moisture conditioning (drying) to achieve compaction. In a relative sense, the clay till should be the least sensitive to changes in moisture content (but still subject to precipitation conditions during construction), with silt being the most sensitive. The clay

till will likely need to be borrowed along the valley slopes at the edges of the project area, while the silt and clay are present on the floodplain (at variable depths) in the vicinity of the proposed alignments. Depending on construction timing and seasonal variations in the groundwater levels, borrow sites located at lower elevations along the floodplain will likely encounter higher moisture contents than borrow sites located at higher elevations along the valley slopes.

- A relatively clean (i.e. less than 10% fines) coarse-grained sand and gravel layer was observed to underlie a significant area of proposed alignment on the south side of the river and was observed to be as shallow as 2.2 m depth below surface. Due to the nature of such fluvial flood plain deposits, the occurrence and continuity of such higher permeability materials is hard to predict. Depending on the final alignment location and the in-situ hydraulic conductivity of the sand and gravel unit, there is potential for significant seepage flow beneath the embankment structure where it is founded over such deposits.
- The water table was consistently reported (by others) to be controlled by the level of the Nechako River (about 2.5 m below ground surface at most locations depending on seasonal variability) along the south side of the river. This suggests a relatively unimpeded hydraulic connection may exist between the near surface soils (silty sands, sand and gravel) and the river, and in turn a potential for significant seepage flow below the proposed embankment structure.
- Near surface, loose to compact sand was observed below the water table in several drill holes on the western portion of the project site (Burrard Avenue, Stewart Street). Depending on the final alignment locations, the potential for seepage-induced static liquefaction of the loose, saturated sands below the embankment structures may exist. Final alignment locations should be assessed for liquefaction potential during the detailed design stage. Analysis for performance of the embankment structure during seismic events was not considered critical nor warranted at this preliminary stage.

6.0 PRELIMINARY DESIGN RECOMMENDATIONS

For the purposes of design, the following preliminary recommendations, with reference to the typical section shown on Figure 2, are provided for the proposed access road and base structures:

General:

- Assume an average stripping depth of 0.3 m. Note that locally deeper areas of soft, wet, weakened and organic soils that are unsuitable for fill foundations are expected. These areas will require special subgrade improvement in terms of sub-excavation and/or additional base reinforcement (e.g. bi-axial geogrid) in order to provide a suitable subgrade bearing surface.

- Use cut slope angles no steeper than 2H:1V for ditch cuts.

- Use fill slope angles no steeper than 3H:1V for access road and base structures.

- Crown the subgrade, sub-base, and base layers to promote drainage by providing a minimum cross fall of 2%. The cross fall should be oriented such that the subgrade surface slopes down and away from the center towards the ditch and/or away from the upstream side of the structure.

- Where required, ditches should maintain a minimum of invert of 150 mm depth below the subgrade surface.

- A non-woven geotextile separator should be placed on the prepared access road subgrade surface, and between the granular and low permeability materials at the interface of the access road and base structure fills. Note that the geotextile should not extend below the low permeability materials in the base structure. Recommended geotextile specifications (based on AASHTO M288-06 "Class 2" geotextile specifications), are listed below in Table 1.

TABLE 1: Recommended Geotextile Specifications

PROPERTIES	VALUE(5)
Material Type	Non-woven
Grab Tensile Strength (N)(1)	>700
Tear Strength (N)(2)	>250
Puncture Strength (N)(3)	>1375
Apparent Opening Size (µm)(4)	100<AOS<220
Recommended Use	Aggregate/Subgrade Separation, Drainage Blanket, or Trench Drain

Notes:
1. ASTM D-4632.
2. ASTM D-4533.
3. ASTM D-6241.
4. ASTM D-4751.
5. All specified properties are based on Minimum Average Roll Values (ASTM C-4759), except Equivalent Opening Size which is based on Maximum Average Roll Value.

Access Roads:

The minimum granular structure recommended for the access roads is given in Table 2. The recommended granular structure provided is judgement and experience based, given the general soil and groundwater conditions, typical regional performance, and the requirement for use by heavy-duty traffic during extreme (i.e. fully saturated) conditions. It is assumed that adequate performance of the access roads will be critical to timely response measures during flood events.

TABLE 2: Recommended Minimum Granular Structure

LAYER	MINIMUM THICKNESS
25 mm minus Well-Graded Base (WGB)	150 mm
75 mm minus Select Granular Sub-Base (SGSB)	750 mm

The granular materials should conform to the aggregate gradation specifications for 25 mm Well Graded Base (WGB) and 75 mm Select Granular Sub-Base (SGSB) given in Table 3, below.

TABLE 3: Recommended Base and Sub-Base Gradations*

SIEVE SIZE (MM)	PERCENT PASSING	
	Well Graded Base (WGB)	Select Granular Sub-Base (SGSB)
75	-	100
50	-	-
37.5	-	-
25	100	-
19	80 – 100	15 – 100
9.5	50 – 85	0 – 100
6.3	-	-
4.75	35 – 70	-
2.36	25 – 50	-
1.18	15 – 35	-
0.600	-	0 – 100
0.300	5 – 20	0 – 15
0.075	0 – 5	0 – 5

* From *2009 Standard Specifications for Highway Construction*, MoT, 2009, Section 202, Table 202-C.

Embankment Structures:

It is recommended that low permeability materials be used to construct the base structure in order to minimize seepage through the structure and below the temporary flood control baskets. Specific borrow source locations for low permeability materials have not been identified at this time; however, according to the BC Dike Design and Construction Guide[1] the low permeability fill materials should generally contain between 15 and 40% passing the 0.075 mm sieve (by weight) with a maximum particle size of 100 mm, and be free from organics, contaminants, and other deleterious materials. The low permeability materials must also be appropriately placed and compacted to provide sufficient bearing capacity for temporary flood control baskets and/or sandbags.

Note that depending on the final alignment locations, design cut volumes, material accessibility and variability, in-situ moisture contents, and other factors, separate off-site borrow sources may be required or determined to be more cost-effective than on-site sourcing. In addition, the subsurface hydrogeological conditions (which are largely unknown at this time) may necessitate further restrictions on base structure material requirements. As the majority of these important details are unknown at this time, final specifications and requirements for low permeability materials should be provided at a later design stage.

[1] BC Ministry of Water, Land & Air Protection, July 2003. "*Dike Design and Construction Guide – Best Management Practices for British Columbia*", Flood Hazard Management Section, Environmental Protection Division. Prepared by Golder Associates Ltd. and Associated Engineering (B.C.) Ltd.

7.0 RECOMMENDATIONS FOR FURTHER WORK

In order to proceed to the detailed design stage of this project, AMEC recommends the following additional tasks be completed:

- Determine likely borrow source locations for construction of the access roads and base structures. Depending on the available materials, adjustments to the proposed preliminary design structure may be required.
- Determine detailed subsurface soil conditions along the final alignments, in particular the alignment locations near Reid Drive on the north side of the Nechako River as very little to no existing information is available.
- Determine hydrogeological properties along the alignment to estimate potential seepage rates and pressures in order to assess effectiveness of the proposed embankment structures. This would likely include in-situ hydrogeological testing such as rising and/or falling head tests or pumping tests.
- Complete additional slope stability and seepage modeling of the proposed design given the updated surface soil and hydrogeological parameters.

8.0 CLOSURE

The recommendations provided within this letter are for preliminary conceptual design purposes only. No specific subsurface geotechnical investigation was carried out by AMEC for this project, and ground conditions can be expected to vary across the project area. The recommendations are based on assumptions and conditions inferred from the information supplied by the District of Vanderhoof and Urban Systems Ltd. as completed by others. AMEC accepts no liability as to the accuracy of information supplied by others, or for different soil conditions that may be encountered. Should ground conditions be encountered that are different from those assumed herein, then AMEC should be retained to revise our recommendations accordingly. Additional site specific subsurface investigation and detailed geotechnical design will be required prior to construction of the proposed works.

This letter has been prepared for the exclusive use by the District of Vanderhoof and their design consultants for the specified application described within. Any use which a third party makes of this letter, or any reliance on or decisions based on it are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this letter.

This letter has been prepared in accordance with generally accepted geotechnical engineering practices. No other warranty, expressed or implied, is made.

Should you have any questions or comments, please do not hesitate to contact any of the undersigned at 250-564-3243.

Respectfully submitted,

AMEC Earth & Environmental
A division of AMEC Americas Limited

Reviewed by

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34249

28-Feb-2011

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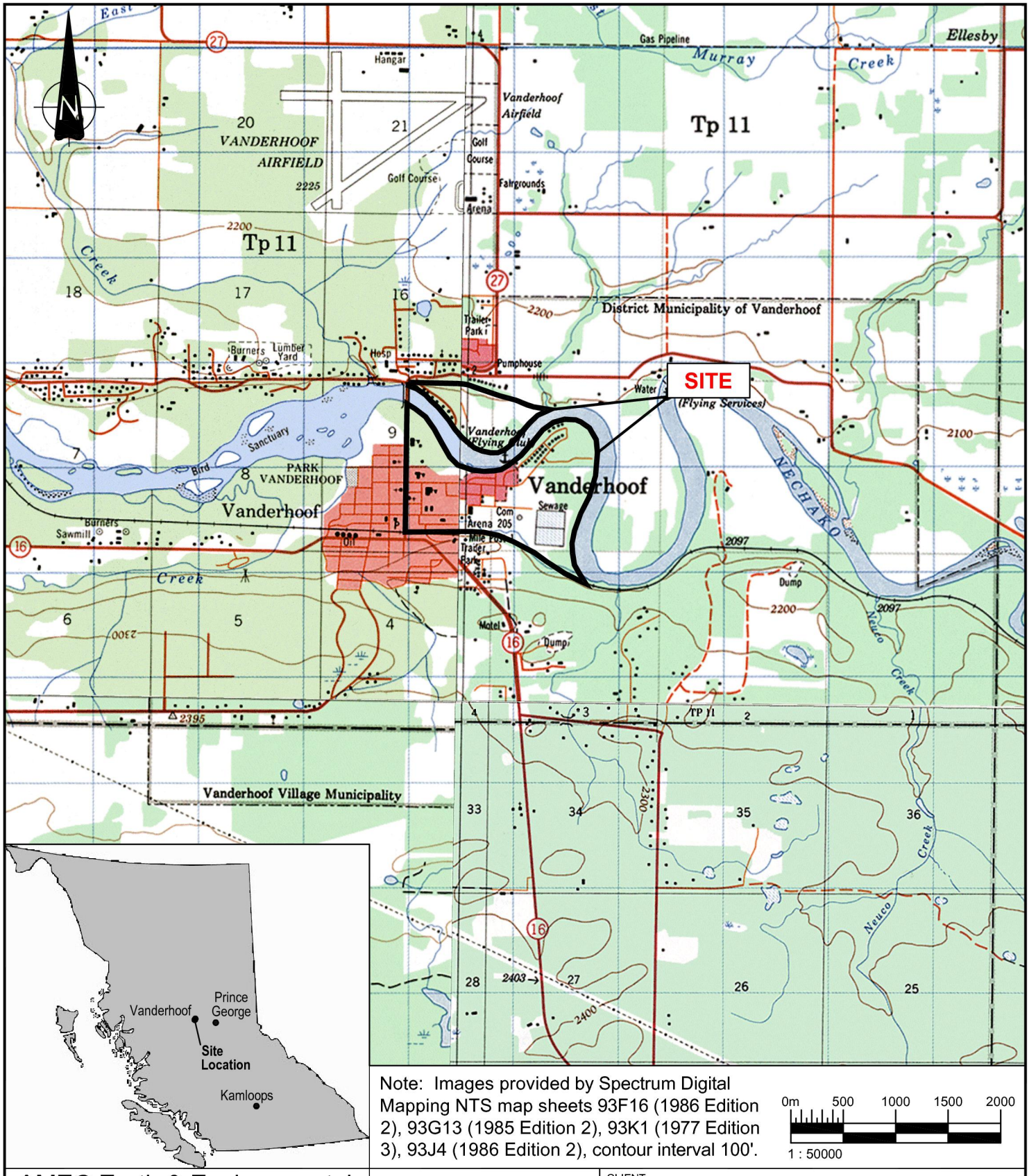
FIGURES



Note: Images provided by Spectrum Digital Mapping NTS map sheets 93F16 (1986 Edition 2), 93G13 (1985 Edition 2), 93K1 (1977 Edition 3), 93J4 (1986 Edition 2), contour interval 100'.

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CLIENT

DISTRICT OF VANDERHOOF
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TITLE: **SITE LOCATION PLAN**	DWN BY: B.Brown	DATUM: NAD27	DATE: 28 FEBRUARY 2011
PROJECT: PRELIMINARY GEOTECHNICAL RECOMMENDATIONS VANDERHOOF FLOOD PROTECTION PLAN VANDERHOOF, BC	CHK'D BY: N.Ekman	REV. NO.: A	PROJECT NO: KX05261
	PROJECTION: UTM Zone 10	SCALE: 1:50 000	FIGURE 1

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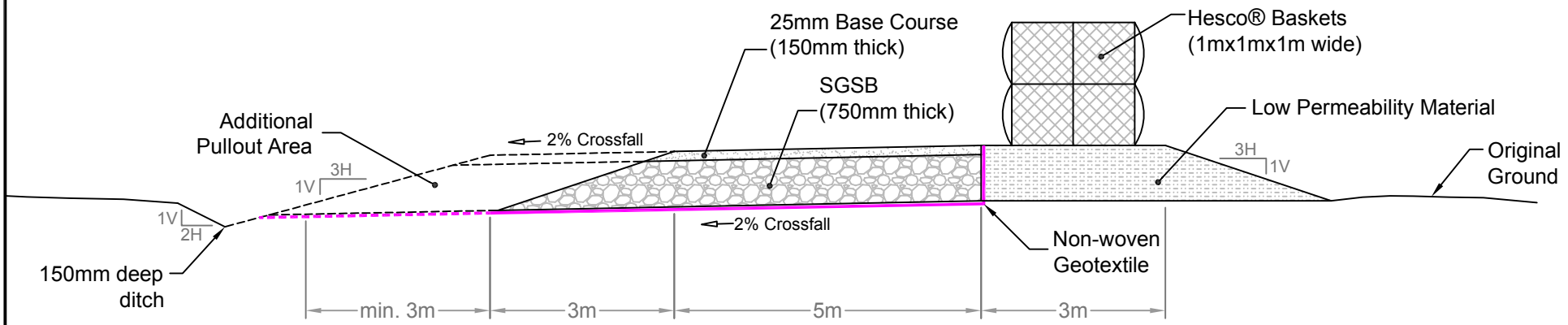
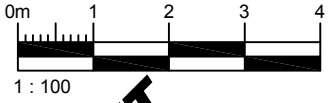
Single Lane with Pull-Outs



Note:
This figure should be read in conjunction with the AMEC letter report titled "Preliminary Geotechnical Recommendations for Works Associated with the Vanderhoof Flood Protection Plan, Vanderhoof, BC", dated 28 February 2011.



DRAFT

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DWN BY: B.Brown
CHK'D BY: N.Ekman
DATUM: NAD83
PROJECTION: UTM Zone 10
SCALE: 1:100

TITLE
TYPICAL SECTION - CONCEPTUAL

PROJECT
PRELIMINARY GEOTECHNICAL RECOMMENDATIONS
VANDERHOOF FLOOD PROTECTION PLAN
VANDERHOOF, BC

REV. NO.: A
DATE: 28 February 2011
PROJECT NO: KX05261

FIGURE 2

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This drawing was originally produced in colour.